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16. ABSTRACT

Technical descriptions and computer programs are presented for two models that calculate long-range transport, diffusion, transformation of SO_2 to sulfate, and dry and precipitation deposition of initially emitted SO_2. One model treats the mixing layer height as constant; the other (at the expense of computer time) varies the mixing layer height diurnally and tracks pollutants in three layers--the daytime mixing layer, the nocturnal ground-based stable layer, and the daytime mixed layer that remains above the nocturnal stable layer. Application of the multi-layer model over a region encompassing the Ohio River Basin produced patterns of SO_2 and sulfate concentrations that are statistically correlated with observed concentrations.

An empirical formula for the transformation rate of SO_2 to sulfate is derived and used in calculations of regional residence times of SO_2 (TSO_2) and sulfate (TSUL) for the U.S. east of 105°W longitude. TSO_2 ranges 15-30 and 15-40 hours for the cold and warm seasons, respectively; TSUL ranges 150-450 and 200-500 hours for the cold and warm seasons, respectively.

Using a cumulus cloud model, results showed that sulfate aerosol capture by cloud water through microphysical processes is sufficient to produce observed levels of sulfate in rain water.

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LONG-RANGE TRANSPORT AND TRANSFORMATION OF SO_2 AND SULFATE

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ABSTRACT

This report provides a technical description and program listing of computational models used in the calculation of long-range transport and transformation of SO_2 and sulfate. Two computer schemes have been developed by which the concentrations of SO_2 and sulfate along trajectories, as well as the average concentration distribution over gridded regions, can be calculated.

In Model A, the effect of the diurnal change of the mixing layer height is not taken into consideration. Trajectories of mean winds in a single layer between the surface and the top of the daytime mixing layer are calculated. The thickness of the layer is kept constant. On the other hand, in Model B, trajectories of the mean winds of the nighttime ground-based stable layer and of the daytime mixing layer, and trajectories of the mean wind of the layer between daytime mixing height and nighttime stable layer height are taken into consideration.

Model B is applied to study the effects of major point sources of SO_2 on the air quality over the area between 35°N and 45°N and between 75°W and 95°W, encompassing the Ohio River basin. The calculated concentrations of SO_2 and of sulfate are compared with data of observed concentrations. It is found that the distribution patterns of calculated concentrations of both, SO_2 and sulfate are statistically correlated with those of observed concentrations.

The observational data on transformation rates of SO_2 to sulfate are scrutinized and an empirical formula for the transformation rate as a function of relative humidity is deduced. Using this formula, calculations are made of the regional residence times of SO_2 and sulfate over the region of the United States east of 105°W longitude, where major industrial sources are located. The regional residence times of SO_2 are in the range between 15 and 30 hours for the cold season, and between 15 and 40 hours for the warm season.

The regional residence time of sulfate is about one order of magnitude greater than that of SO_2, ranging between 150 and 450 hours for the cold season and between 200 and 500 hours for the warm season.

Using a cumulus model, sulfate content in rainwater is calculated. It is found that aerosol capture by cloud water through microphysical processes is efficient enough to produce observed levels of sulfate content in rainwater.

Future research needs in further development of this study are also described.

This report was submitted in fulfillment of Grant No. R 805271 by Colorado State University under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period May 1, 1977, to April 30, 1979. Work was completed as of April 30, 1979.

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LIST OF SYMBOLS

C_1	concentration of SO_2
C_{10}	initial concentration of SO_2
C_{11}	concentration of SO_2 after time interval t_1
C_2	concentration of sulfate
C_{20}	initial concentration of sulfate
C_{21}	concentration of sulfate after time interval t_1
C_{2m}	maximum concentration of sulfate
d	length of trajectory segment
f	probability of precipitation
H_1	nighttime stable layer height
H_2	daytime mixing layer height
$\bar{H}$	mean mixing layer height
h	upper value of integral with respect to height
h_o	bottom value of integral with respect to height
K	transformation rate of SO_2 to sulfate
k_{p1}	depletion rate of SO_2 due to precipitation
k_{p2}	depletion rate of sulfate due to precipitation
L	mean width of pollutant plume
L_o	width of the original source area
L_1	width of pollutant plume at time step 1
N	number of days multiplied by the number of trajectories per day

P	precipitation rate
$\bar{P}$	mean precipitation rate
RH	relative humidity
R_1	quantity representing SO_2 removal terms
R_2	quantity representing sulfate removal terms
T_{SO_2}	residence time of SO_2
T_{SUL}	residence time of sulfate
t	distance defined as a function of d and Σ_h
t	time
t_n	time interval n
$\bar{u}$	mean wind speed
Vd	vertical velocity through the top of the mixing layer
Vg	deposition velocity
Vg_1	deposition velocity of SO_2
Vg_2	deposition velocity of sulfate
V_s	precipitation scavenging velocity
$\bar{V}_x$	x-component of mean wind
$\bar{V}_y$	y-component of mean wind
X_1	distance of trajectory segment at time interval t_1
z	distance between grid point and trajectory endpoint
α	angle between a latitude circle and a trajectory segment
β	angle between distance d and distance t
σ	angle extending between the line Z and a latitude circle
δ_1	angle defined as $\alpha + \pi/2$
δ_2	angle defined as $\alpha + 3\pi/2$
ε	angle defined as a function of d and Σ_h

θ_{n-1}	longitude of the endpoint of trajectory segment at time step n-1
θ_n	longitude of the endpoint of trajectory segment at time step n
κ	concentration of a pollutant in rainwater
λ_{d_1}	depletion rate of SO_2 due to dry deposition
λ_{d_2}	depletion rate os sulfate due to dry deposition
λ_p	scavenging rate due to precipitation
Σ_h	mean width of pollutant plume
σ_{v_h}	dispersion parameter
σ_{v_x}	standard deviation of x-component wind
σ_{v_y}	standard deviation of y-component wind
τ_d	duration of dry period
τ_p	duration of wet period
χ	concentration of pollutant in air
ψ_{n-1}	latitude of the endpoint of trajectory segment at time step n-1
ψ_n	latitude of the endpoint of trajectory segment at time step n

ACKNOWLEDGMENT

The trajectory calculation portion of our models in this report is an expansion and modification of an original scheme developed by Heffter and Taylor (1975).

Programming help by Ms. Ann M. Starr and Mr. Dan R. Westhoff are greatly appreciated.

The distributions of 10-day average concentrations of SO_2 and sulfate, were calculated on the EPA computer. Mr. Adrian Busse was very helpful in running our program on the computer. Thanks are also due to the project officer, Mr. G.C. Holzworth, for giving us constructive suggestions and providing necessary data.

CHAPTER 1

INTRODUCTION

Growing reliance upon coal as a fuel for power generation has increased the international and national concern about SO_2 and sulfate pollution. Recent observational evidence in the U.S. and Europe indicates that exposure to sulfate aerosols and ozone is possible over large regions extending for hundreds of kilometers downwind from major sources.

In our previous studies under EPA Grant No. R803685, we have developed a long-range transport model suitable for keeping track of pollutants downstream of large industrial complexes (Henmi et al., 1977, 1978). Transport modelling plays an important role in understanding the relationship between anthropogenic SO_2 emission and atmospheric concentrations of SO_2 and sulfate, and serves as a basis for the simulation of present and future changes in pollutant concentrations and in atmospheric parameters such as visibility, turbidity and acidity of rainwater.

In order to estimate the fate of pollutants in the atmosphere, the transport in each of the following layers must be studied:

(1) Nighttime stable layer and daytime mixing layer containing a near-uniform vertical distribution of pollutants;

(2) The layer between daytime mixing height and nighttime stable-layer height, in which pollutants are trapped during the nighttime;

(3) The free atmosphere containing pollution which has been carried up, beyond the range of boundary-layer mixing, by large-scale ascent or by penetrative convection.

Taking into consideration the transports in the layers described in (1) and (2), we have developed long-range transport and transformation models of SO_2 and sulfate. The details of our models are described in Chapters 4 and 5. Comparisons between the observed concentrations of SO_2 and sulfate and those calculated by the model are described in Chapter 6.

In previous studies (Henmi et al., 1977, 1978), we considered the determination of the residence time of SO_2 in the mixing layer. Assuming that precipitation, deposition and the transformation into sulfate are the mechanisms of removal, the regional residence time of SO_2 was calculated for the region of the United States east of 105°W latitude. However, the shortcoming of this study was that the fate of sulfate had not been considered. During the present contract period, we have extended this study to include the residence time of sulfate. The results are described in Chapter 7.

The concentration of sulfate in precipitation is a consequence of several microphysical processes occurring within and beneath the clouds. The microphysical processes include Brownian motion, inertial impaction and nucleation. In Chapter 8, taking into consideration these processes, a numerical study is performed on the sulfate concentration in rainwater.

CHAPTER 2

CONCLUSION

One of our principal objectives under Research Grant No. R 805271 has been to develop computer models for the study of long-range transport and transformation of SO_2 and sulfate. These models are intended for use with input parameters obtainable routinely from the national meteorological services. We have developed two computational schemes by which the concentrations of SO_2 and sulfate along trajectories, as well as the average concentration distributions over gridded regions, can be calculated. In Model A, trajectories of the mean wind in a single layer between the surface and the top of the daytime mixing layer are calculated. In Model B, we take into consideration the trajectories of the mean wind in (a) the layer between the surface and the top of the daytime mixing layer, (b) the layer between the surface and the top of the nighttime stable layer (i.e. the height of the ground-based inversion layer in which pollutants are essentially "trapped"), and (c) the layer between the nighttime stable layer and the daytime mixing height. Because of the more realistic assumptions on the diurnal variation of the mixing height, Model B is superior to Model A, however it requires more computer time to run.

The characteristics of these models can be summarized as follows:

1. As input data, wind speed and direction which are observed by radiosonde, and relative humidity and precipitation data observed at the surface are utilized.

2. The transformation rate of SO_2 to sulfate is expressed as a function of relative humidity, and the wet removal rate is parameterized as a function of precipitation rate and precipitation probability.

3. The program can be applied to any region over the northern hemisphere where input data are available.

Model B was applied to calculate the geographical distributions of average concentrations of SO_2 and sulfate over the region between 35°N and 45°N and between 75°W and 95°W which encompasses the Ohio River basin. The distribution patterns of the calculated concentrations of SO_2 and of sulfate were statistically correlated with the patterns of observed concentrations.

The regional residence times of SO_2 and sulfate were calculated for the region of the United States east of 105°W longitude. The regional residence times of SO_2 were in the range between 15 and 30 hours for the cold season and in the range between 15 and 40 hours for the warm season. The regional residence time of sulfate was about one order of magnitude greater than that of SO_2, ranging between 150 and 450 hours for the cold season and between 200 and 500 hours for the warm season.

Using a cumulus model, sulfate content in rainwater was calculated. Although the study has shown that microphysical processes such as condensation, Brownian diffusion, attachments due to thermophoresis and diffusiophoresis can be efficient enough to attain the sulfate content of rainwater which has been observed, this conclusion should be regarded as tentative. The combined effects of the microphysical processes and of SO_2 oxidation to sulfate in water must be studied in the future.

CHAPTER 3

RECOMMENDATIONS

3.1. REFINEMENT OF THE MODEL

Although our efforts of developing the model have reached the stage where the distribution of average concentrations, as well as deposition amounts of SO_2 and sulfate due to a multitude of sources can be calculated, there are still several aspects to be improved.

3.1.1. Saving of Computing Time

The model (Model B) in the present version requires, on the EPA computer (UNIVAC 1100A), about five hours of computing time to calculate 10-day average concentrations of SO_2 and sulfate emanating from 60 sources, and the deposition amounts of these two pollutants over an area of 10 degrees latitude by 20 degrees longitude. The results of the calculations are described in Chapter 6. In the model, more than 90 percent of the computing time is spent in interpolation schemes of concentrations along the trajectories into grid point values. It seems that improvement of this interpolation scheme is the key to utilizing computer time in a more economic way.

3.1.2. Improvement of the Expression of Transport Process Near the Source

In the present model, the assumption is made that pollutants are instantaneously and uniformly mixed into the mixing layer after being emitted from the sources. In order to improve the performance of the model, more realistic formulas to express concentrations, particularly for the first 6 to 12 hours, must be considered.

3.1.3. Use of Daily Radiosonde Data for the Calculation of the Mixing Height

Climatological averages of the heights of the daytime mixing layer and of the nighttime stable layer determined by Holzworth (1972) have been used in the model. For the calculation of the concentration distributions for a short time period, it is desirable to determine the mixing heights based on twice daily radiosonde data.

3.1.4. Modification of the Model for Climatological Data

It is possible to calculate long-term (seasonal or annual) average concentrations, using the present model repeatedly. However, due to the large amount of computing time required for this process, it is not practical to do so. Statistical studies of trajectories, dispersion parameters, mixing height, precipitation and relative humidity over the period of interest must be carried out. The model will have to be modified to handle statistical distributions of these parameters.

3.2. VERIFICATION OF THE MODEL

In Chapter 6, we describe our preliminary efforts to verify the model. Further tests should be conducted using actual concentration data of SO_2 and sulfate observed at stations within the area of interest. There exists a strong correlation between aerosol mass concentrations in the size range of 0.1 to 1 micron in diameter and the extinction of light by scattering (Charlson, 1969; Hidy et al., 1976). Furthermore, measurements in and near St. Louis, MO, have shown that sulfates often account for 50 percent or more of the aerosol mass in this size range (Charlson et al., 1974). Therefore, comparisons of the geographical distribution of visibility with the sulfate distribution derived from our calculations seems a useful means to verify the model.

3.3. APPLICATION OF THE MODEL TO STUDY FUTURE AIR QUALITY

Once a reliable model performance is assured, the model shall be applied to study the effects of future emission sources on regional air quality, dry deposition and acid rain climatology. The model application should focus on such questions as the impact of dramatically increasing coal use in the Midwest, the impact of the Ohio River basin emissions on the New England states, etc. The results of such studies will serve as useful tools in formulating a national pollution control in the face of the urgently needed development of new energy sources.

CHAPTER 4

EXPLANATION OF MODELS

Models A and B each consist of two separate programs:

(1) A program that calculates the trajectories of plumes leaving from any chosen source area(s), dispersion parameters, and the parameters necessary for concentration calculations along trajectory segments using observed wind data.

(2) A program that calculates the concentrations of sulfur dioxide and sulfate along trajectory segments and interpolates the plume concentrations to grid intersections.

A program that calculates trajectories was originally developed by NOAA's Air Resources Laboratories (Heffter and Taylor, 1975) and has been substantially modified for our purpose. In the following, the details of our program will be described using examples.

4.1 CALCULATIONS OF TRAJECTORIES, DISPERSION PARAMETER AND OTHER PARAMETERS

4.1.1 Trajectories

In Model A, as mentioned previously, the effect of the diurnal change of mixing layer height is not taken into consideration. Trajectories of mean winds in a single layer between the surface and the top of the daytime mixing layer are calculated. The thickness of the layer is kept constant. On the other hand, in Model B, trajectories of mean winds of the nighttime stable layer and daytime mixing layer, and trajectories of the mean winds of the layer between daytime mixing height and nighttime stable layer height are taken into consideration. In Figure 1 we show how trajectories of the mean wind starting at different times are calculated by Model B. The program is capable of calculating trajectories either four times a day originating at 00, 06, 12, and 18 GMT, or two times a day originating at 00, and 12 GMT. It is designated in the program that the time between 00 GMT (18 CST) and 12 GMT (6 CST) is nighttime and the time between 12 GMT (6 CST) and 00 GMT (18 CST) is daytime. In Fig. 1, H_1 is the nighttime mixing height and H_2 is the daytime mixing height. Solid lines and broken lines indicate daytime and nighttime trajectory segments, respectively. K = 1 describes the case in which the air trajectory leaves the origin at 00 GMT (18 CST). In this case we assume that the pollutants emanating from the surface are contained and transported in the nighttime mixing layer. At 12 GMT (6 CST), the pollutants

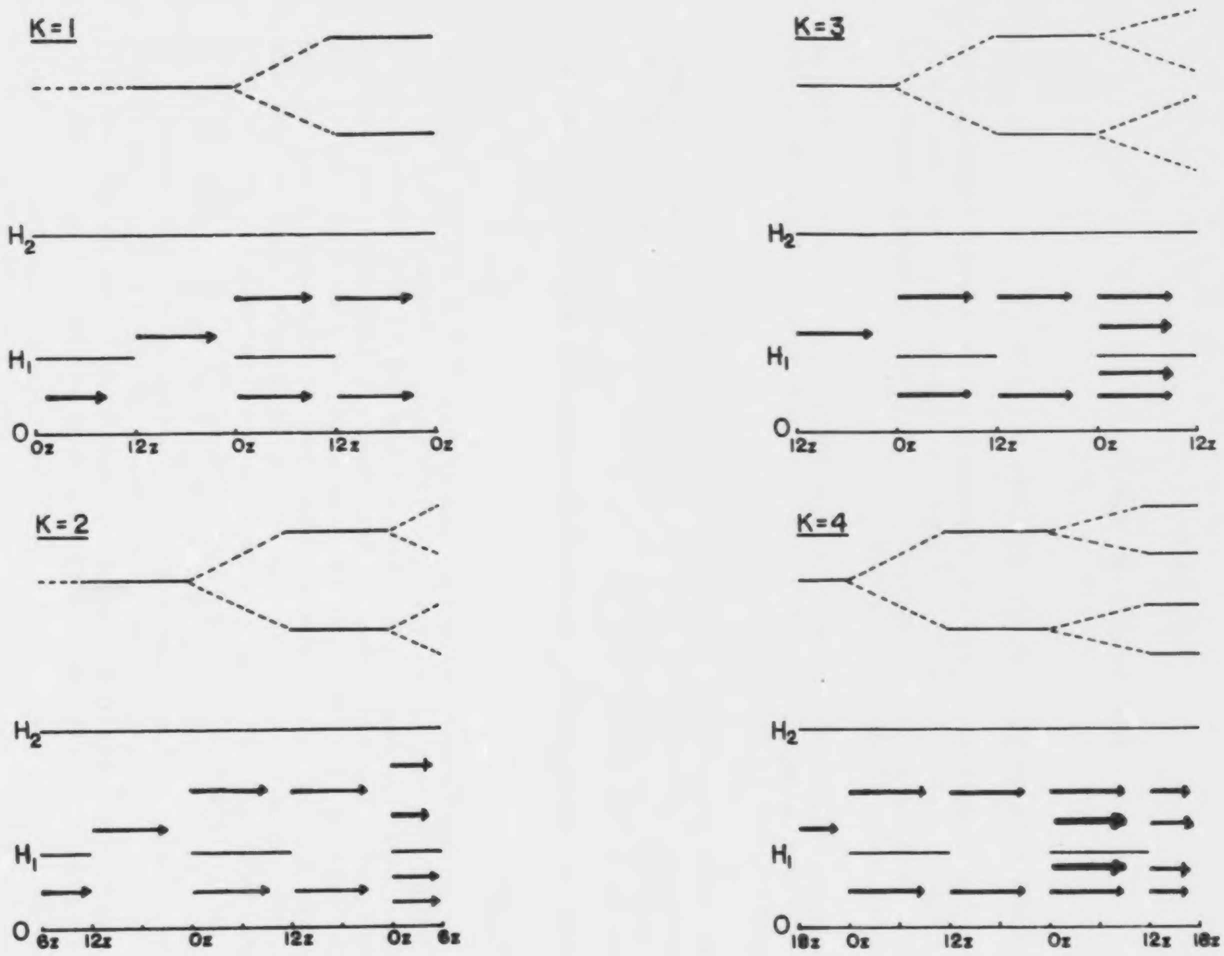
K=1
H2
H1
O
0z
12z
0z
12z
0z
K=3
H2
H1
O
12z
0z
12z
0z
12z
K=2
H2
H1
O
6z
12z
0z
12z
0z
6z
K=4
H2
H1
O
18z
0z
12z
0z
12z
18z

Figure 1. Schematic diagram showing how trajectories starting at different times (K) are calculated in Model B. For each K the upper diagram shows how the horizontal projection of trajectories may split and the lower diagram shows how trajectories appear in vertical layers.

contained in this nighttime stable layer become mixed uniformly into the daytime mixing layer due to convective mixing spawned by radiational heating. At 00 GMT (18 CST) of the second day, the pollutants distributed uniformly below the daytime mixing height are separated into two layers, the layer between the surface and the nighttime stable layer height, and the layer between the nighttime stable layer height and daytime mixing height. The air masses in the two layers take different tracks. At 12 GMT (6 CST) of the second day, the pollutants which followed different tracks during the previous night, are again mixed into the daytime mixing layer. K = 2, 3 and 4 correspond to the cases where trajectories leave at 06 GMT (24 CST), 12 GMT (6 CST) and 18 GMT (12 CST), respectively. The figure shows that, for two-day periods, a single trajectory at the beginning separates into four different trajectories.

Figures 2 and 3 are examples of calculated trajectories starting on May 1 and 2, 1974, respectively. The origin of these trajectories is located at 38.4°N and 90.1°W. In these figures, trajectories calculated using Model A are drawn with thick broken lines. Trajectories drawn with solid lines represent daytime segments and those with broken lines represent nighttime segments of trajectories.

4.1.2 Dispersion Parameter

The dispersion parameter σv_h defined as

$$\sigma v_h = \frac{\sigma v_x \cdot |\bar{V}_y| + \sigma v_y \cdot |\bar{V}_x|}{\bar{u}} \tag{1}$$

is calculated along each trajectory segment. $\bar{V}_x$ and $\bar{V}_y$ are the x- and y-components of the mean wind, $\bar{u}$ is the mean wind speed, and σv_x and σv_y are defined as

$$\sigma v_x = \left[\frac{\int_{h_o}^{h} (V_x[z] - \bar{V}_x)^2 \, dz}{h - h_o} \right]^{1/2} \tag{2}$$

$$\sigma v_y = \left[\frac{\int_{h_o}^{h} (V_y[z] - \bar{V}_y)^2 \, dz}{h - h_o} \right]^{1/2} \tag{3}$$

Here, h and h_o are the top and the bottom of the layer. Details of derivation of σv_h have been described by Henmi et al. (1977, 1978). After the

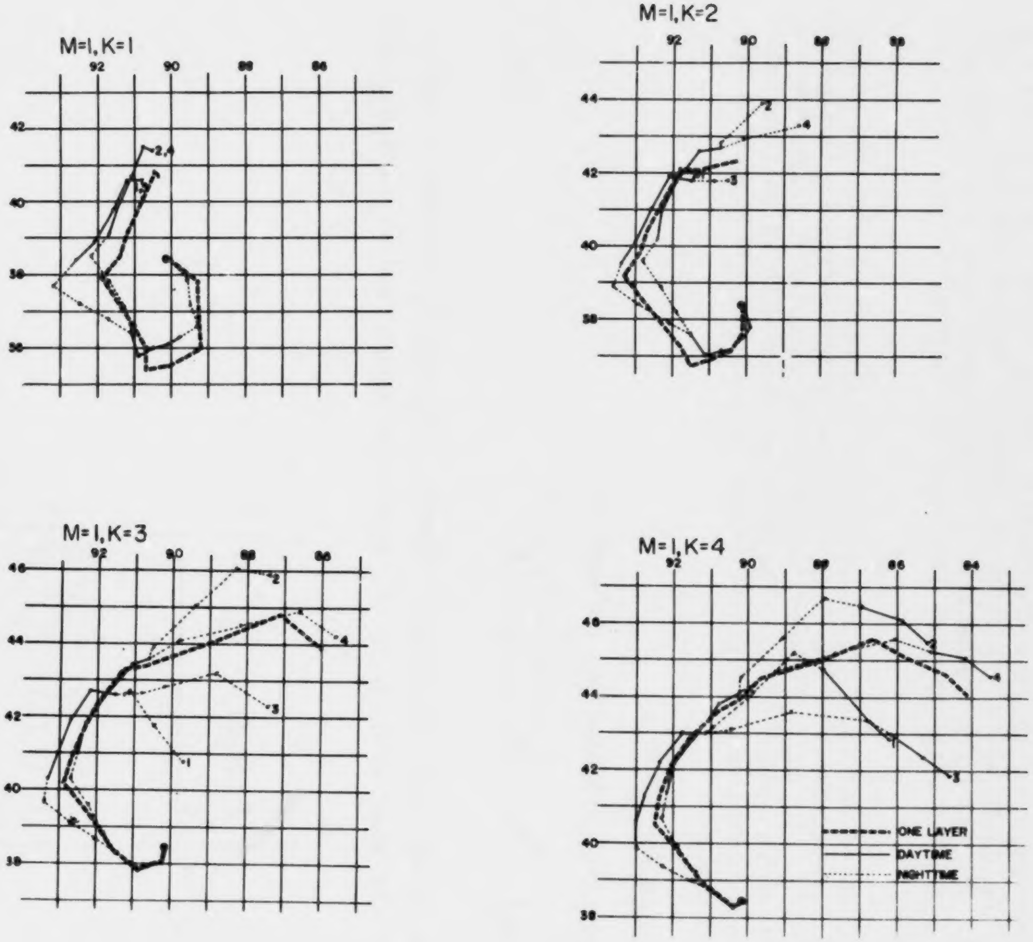

Figure 2. Examples of trajectories originating at 38.4°N and 90.1°W, starting on May 1, 1974. K = 1, 2, 3, and 4 correspond to the starting times of 00, 06, 12, and 18 GMT, respectively. M = 1 correspond to day number. Number(s) at the end of trajectories are for identification. Where trajectories have split, the smaller number designates the layer between surface and nighttime stable layer height.

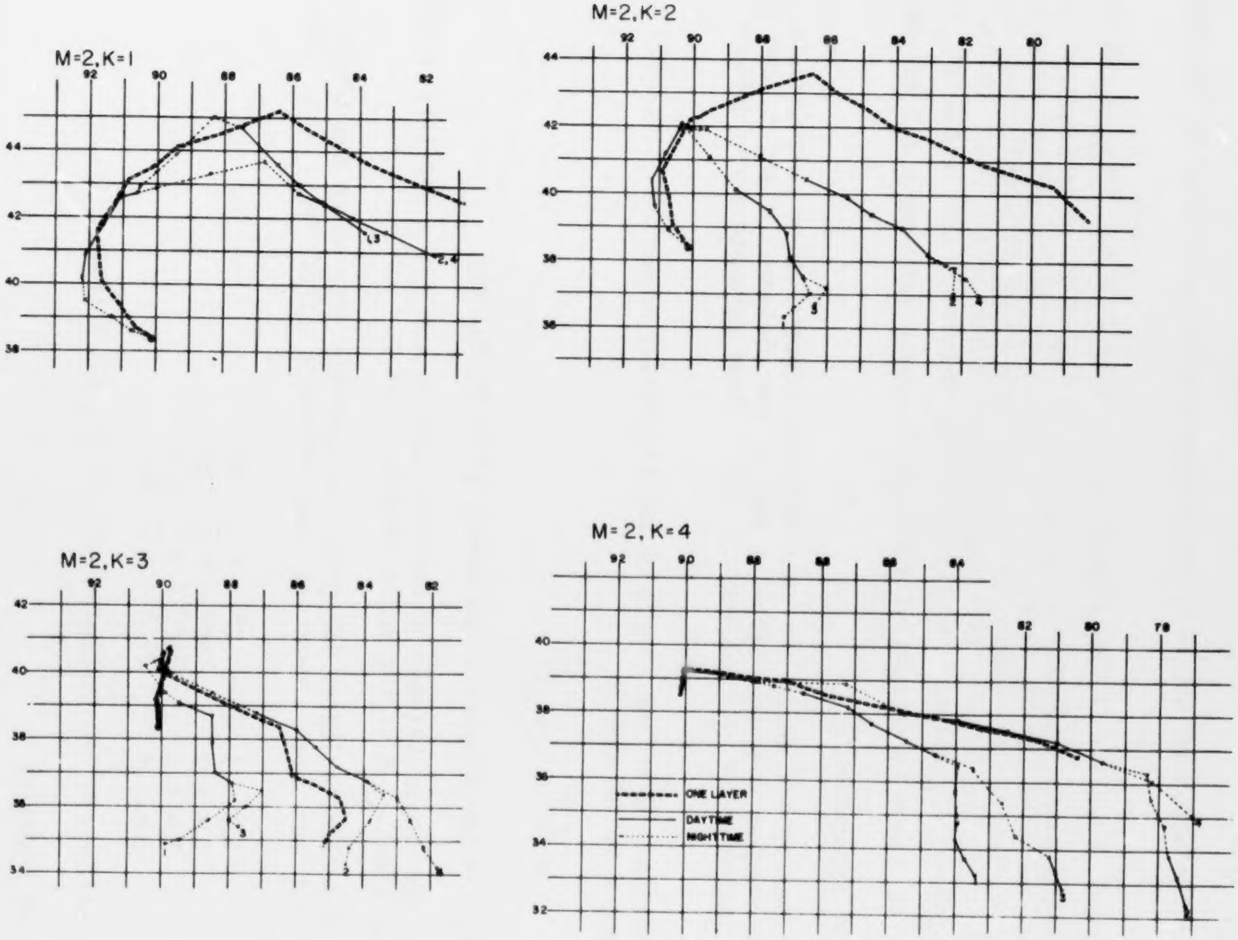

Figure 3. Similar to Figure 2, except trajectories starting on May 2, 1974.

trajectory analysis has been repeated for n time steps of equal length, the mean width of the pollutant plume L or Σ_h along the mean wind is given by

$$L = \Sigma_h = 2(\sigma v_{h,1} \cdot t + \sigma v_{h,2} \cdot t + \ldots + \sigma v_{h,n} \cdot t) + L_o \qquad (4)$$

where L_o is the width of the original source area perpendicular to the mean wind.

Figures 4, 5, 6 and 7 show examples of Σ_h with $L_o = 0$. These Σ_h values were calculated along trajectories exhibited in Figure 2. M in Figure 4 indicates the number of the day (e.g. 1, 2, 3, etc.) of the trajectory calculation and K indicates the number of the six-hour interval within that day, during which the trajectory was started. The thick solid lines in these figures represent Σ_h-values calculated using Model A. The width of the plume, Σ_h, is given in degrees of latitude (1 degree latitude = 111.137 Km).

4.1.3 Other Parameters

Other parameters which are necessary for concentration calculations in the second program are the angles α and β, the distances d and t, and the direction indicator of the trajectory, IJK. These parameters are defined in Figure 8.

The distance d is the length of the trajectory segment at time step t_n. The distance t is defined as

$$t = \sqrt{d^2 + \Sigma_h(t_n)^2}$$

where $\Sigma_h(t_n)$ is the dispersion parameter given by Eq. (4).

α is the angle between a latitude circle and the trajectory segment during time step t_n; β is the angle between d and t.

The direction indicator IJK gives the quadrant into which the trajectory points. East has been chosen as the reference direction. Thus, IJK is defined as

IJK = 1 for $0° \leq \alpha \leq 90°$
IJK = 2 $90° < \alpha \leq 180°$
IJK = 3 $180° < \alpha \leq 270°$
IJK = 4 $270° < \alpha < 360°$

4.2 CALCULATIONS OF THE CONCENTRATIONS OF SO_2 AND SULFATE

4.2.1 Basic Equation

Realizing that our knowledge about the transformation rate of sulfur dioxide to sulfate at the present does not justify incorporation of anything more complex than the parameterization of linearized kinetics, the following two equations for the calculation of concentrations of sulfur dioxide and sulfate are used:

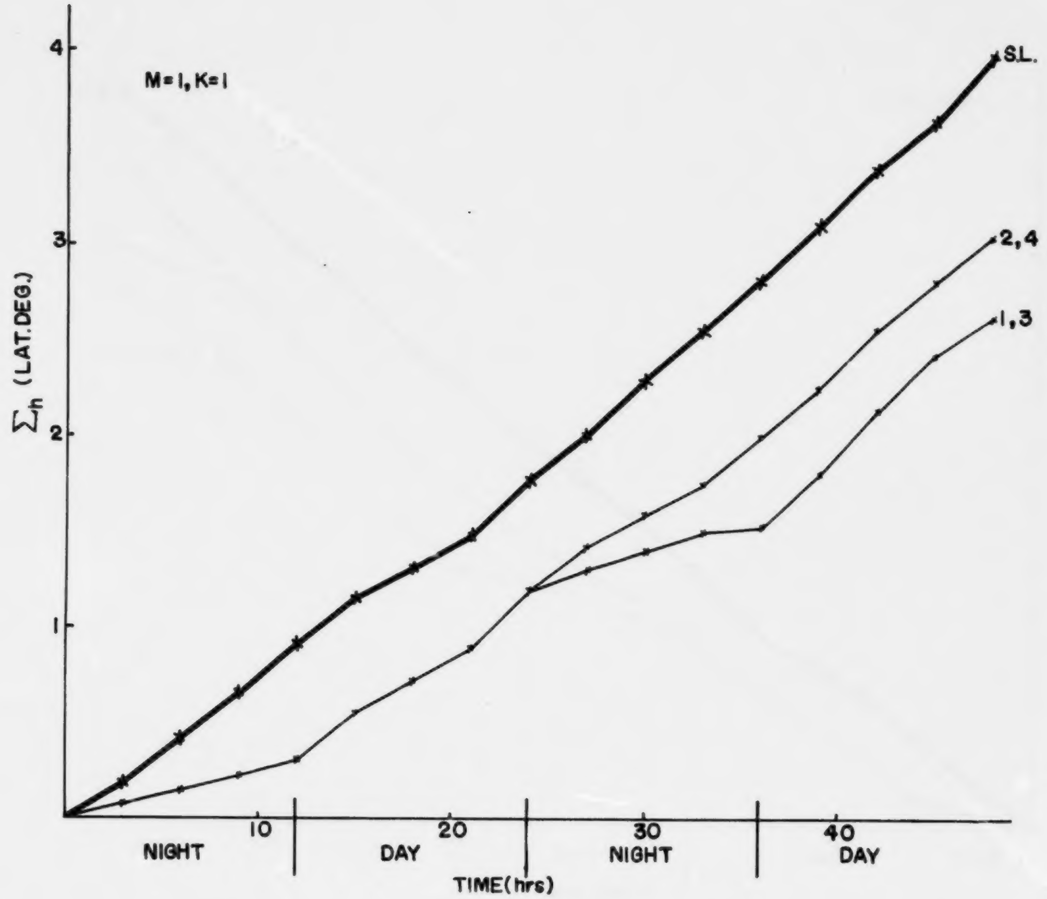

Figure 4. Example of Σ_h along trajectories for M = 1, K = 1. S.L. indicates "Single-Layer Model" A; 1, 2, 3, and 4 are trajectory numbers in Model B as shown in Fig. 2.

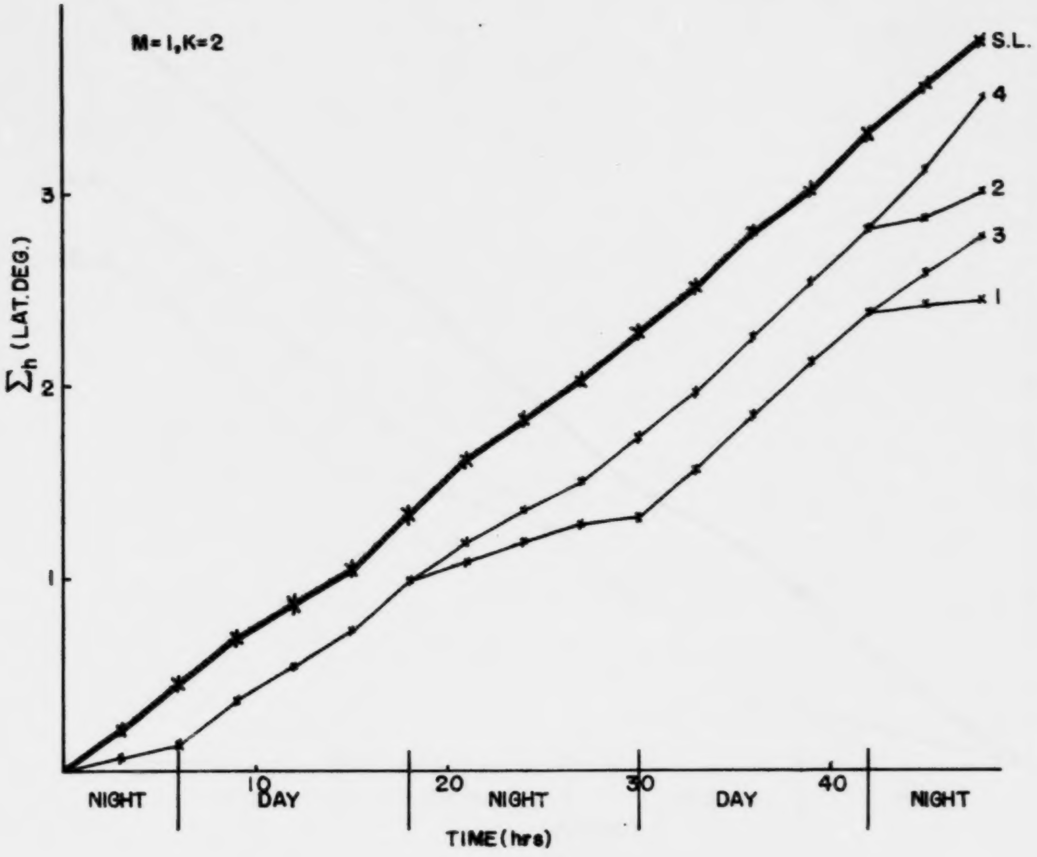

Figure 5. Example of Σ_h along trajectories for M = 1, K = 2.

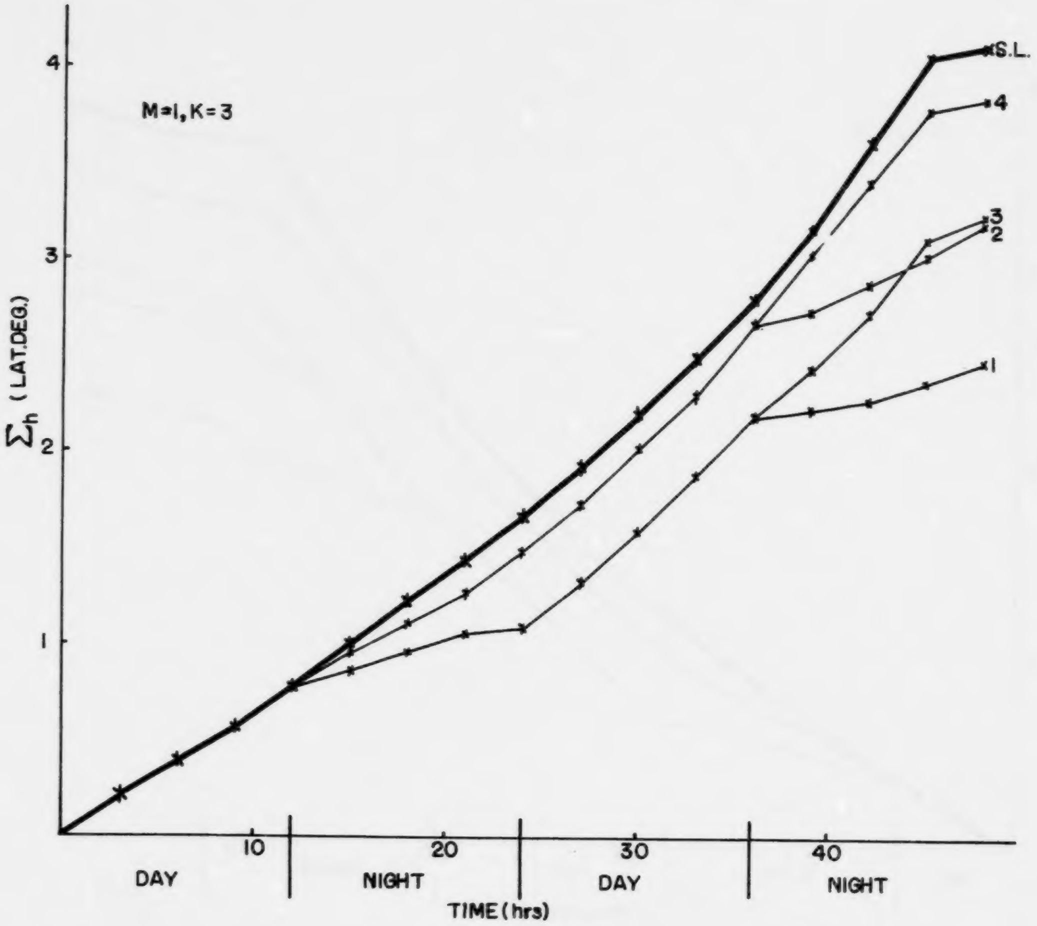

Figure 6. Example of Σ_h along trajectories for M = 1, K = 3.

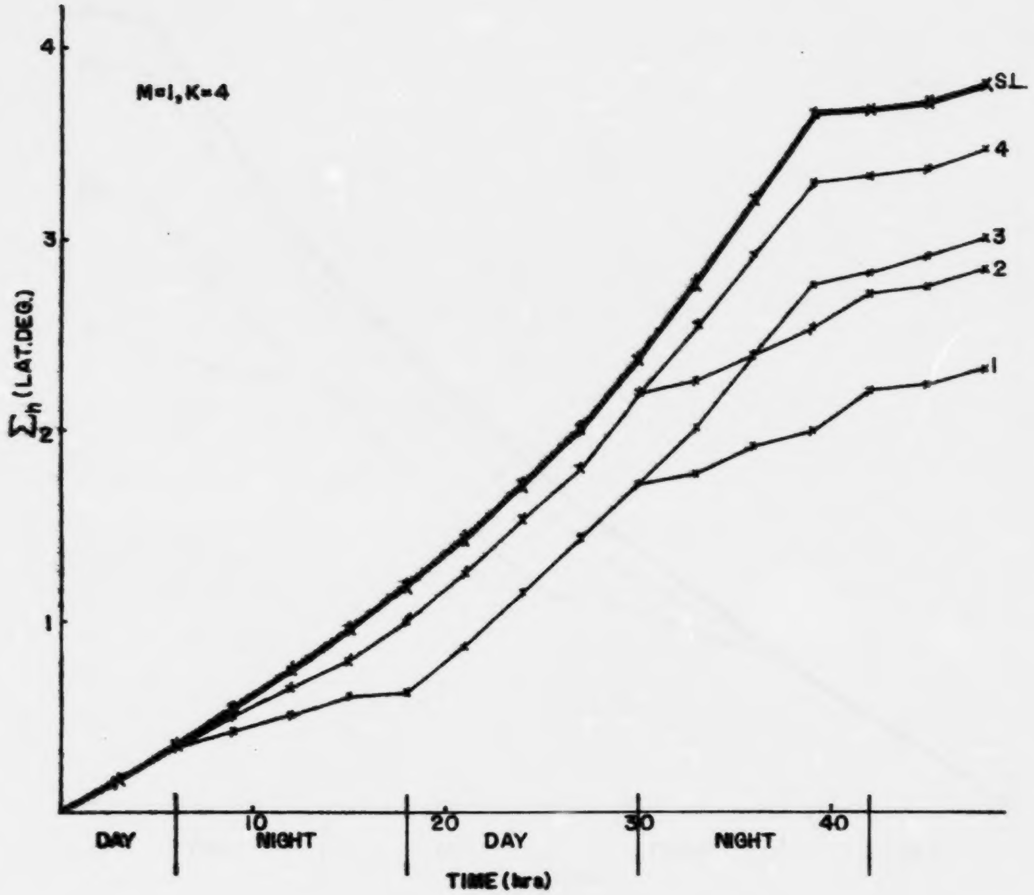

Figure 7. Example of Σ_h along trajectories for M = 1, K = 4.

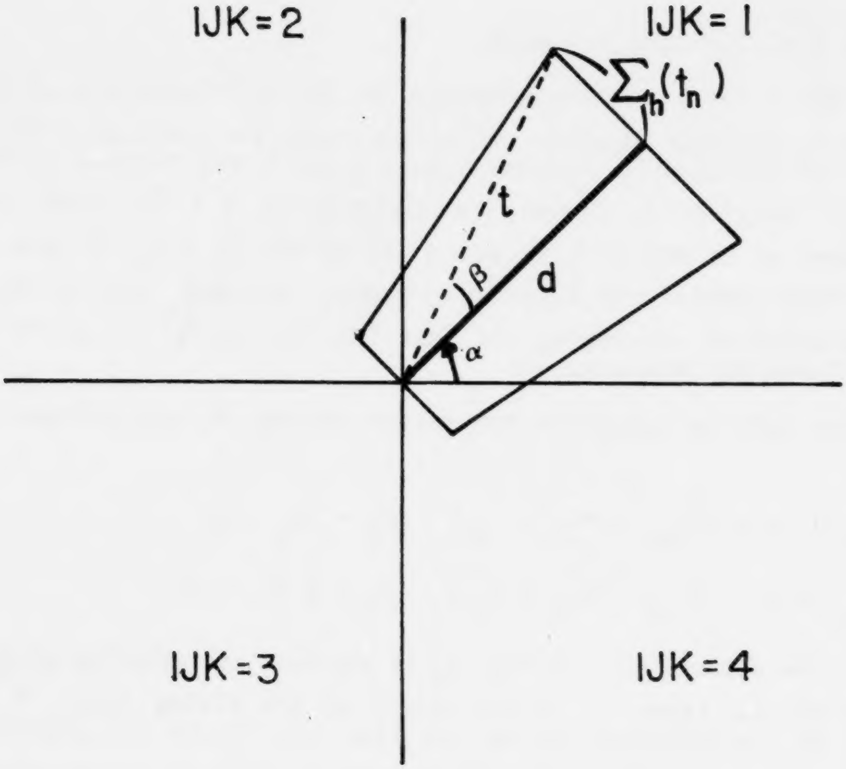
IJK=2
IJK=1
$\sum_h(t_n)$
t
β
d
α
IJK=3
IJK=4

Figure 8. Definition of α, β, d and t. (For explanation see text.)

Let us assume that the pollutants are transported with the mean wind speed $\bar{u}$, as shown in Fig. 9, from an initial vertical plane at location "0" in which the concentrations C_{10} and C_{20} are uniformly distributed. C_{10} and C_{20} are, respectively, the initial concentrations of sulfur dioxide and sulfate. The width of the source area perpendicular to the mean wind is taken as L_o, its height is h, equivalent to the height of the mixed layer. After time $t = x/\bar{u}$ the pollutants cross a vertical plane P at a distance x, from the source area. The width of the plume at P is defined as

$$L(x) = L_o + 2\sigma v_h \cdot t \tag{5}$$

where σv_h is the dispersion parameter.

If C_1 and C_2 are the concentrations of sulfur dioxide and of sulfate at distance x, the rate at which pollutants cross the vertical plane P are $\bar{u}\cdot h\cdot L(x)\cdot C_1$ and $\bar{u}\cdot h\cdot L(x)\cdot C_2$. Assuming that $\bar{u}$ and h are constant during the time interval required to travel the distance dx, the net rates of loss between planes at x and x + dx are given by $\bar{u}\cdot h\cdot\frac{d}{dx}(LC_1)\cdot dx$ and $\bar{u}\cdot h\cdot\frac{d}{dx}(LC_2)\cdot dx$. These amounts are balanced by removal processes such as dry deposition, precipitation scavenging and loss from the top of the mixed layer, and by transformation processes.

The mass balance equations for sulfur dioxide C_1 and sulfate C_2 are given by

$$\bar{u}\cdot h\,\frac{d}{dx}(LC_1) = -[V_{g1} + fV_{s1} + V_{d1}]\cdot LC_1 - KC_1\cdot Lh \tag{6}$$

$$\bar{u}\cdot h\,\frac{d}{dx}(LC_2) = -[V_{g2} + fV_{s2} + V_{d2}]\cdot LC_2 + \frac{3}{2}KC_1\cdot Lh \tag{7}$$

where V_g is the deposition velocity, V_d is the vertical velocity through the top of the mixing layer, h is the height of the mixing layer, f is the probability of precipitation during the time $x/\bar{u}$, V_s is the precipitation scavenging velocity and K is the transformation rate of sulfur dioxide to sulfate. Subscripts 1 and 2 stand for sulfur dioxide and sulfate, respectively. The ratio $\frac{3}{2}$ is the ratio of molecular weights of sulfate ($SO_4^{=}$) to sulfur dioxide (SO_2).

The solutions to Eqs. (6) and (7) are given by

$$C_1 = \frac{C_{10}\cdot L_o}{L_o + 2\sigma vh\,\frac{x}{\bar{u}}}\cdot\exp\left[-\frac{R_1}{h}\cdot\frac{x}{\bar{u}}\right] \tag{8}$$

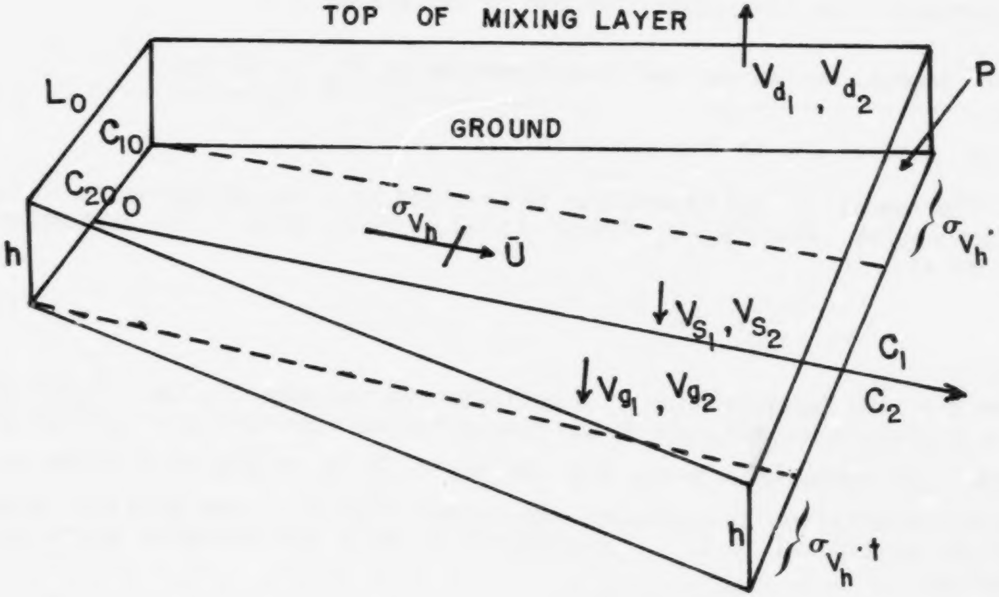
TOP OF MIXING LAYER
V_{d_1} , V_{d_2}
P
L_0
C_{10}
GROUND
C_{20}
0
σ_{v_h}
$\bar{U}$
$\sigma_{v_h} \cdot t$
h
V_{s_1} , V_{s_2}
C_1
V_{g_1} , V_{g_2}
C_2
h
$\sigma_{v_h} \cdot t$

Figure 9. Schematic diagram of the models.

$$C_2 = \frac{C_{20} \cdot L_o}{L_o + 2\sigma v h \frac{x}{\bar{u}}} \cdot \exp\left[-\frac{R_2}{h} \cdot \frac{x}{\bar{u}}\right]$$

$$+ \frac{3}{2} K \frac{h}{R_1 - R_2} \cdot \left\{C_1 \exp\left[\frac{R_1 - R_2}{h} \quad \frac{x}{\bar{u}}\right] - 1\right\} \qquad (9)$$

where $R_1 = V_{g1} + fV_{S1} + V_{d1} + K \cdot h$, and $R_2 = V_{g2} + fV_{s2} + V_{d2}$. Equations (8) and (9) can be applied along a trajectory as follows: After the first interval, t_1, of trajectory analysis, the concentrations of the pollutants at the endpoint of a trajectory segment, x_1, are calculated as C_{11} and C_{21} and are regarded as the concentrations of the new hypothetical line source with the width of $L_1 = L_o + 2\ v_{h1}\ t_1$. By repeating this calculation process for successive trajectory elements, the concentrations along the trajectory at any distance from the source area can be calculated.

4.2.2 Removal Mechanisms and Transformation of SO_2 to Sulfate

4.2.2a Removal Due to Precipitation

The removal of pollutants due to precipitation can be expressed in terms of scavenging velocity, V_s (Henmi et al., 1977, 1978). The parameter is defined as

$$V_s = \left(\frac{\kappa}{\chi}\right)_v \cdot P \qquad (10)$$

where κ is the concentration of a pollutant in rainwater, χ the concentration of a pollutant in air, and P the precipitation rate during a precipitation event. The subscript v means that the ratio $\left(\frac{\kappa}{\chi}\right)$ is formed on a volume basis. Since precipitation is episodic, the probability of a precipitation event f must be multiplied to V_s. The probability of a precipitation event is defined as

$$f = \frac{\tau_p}{\tau_d + \tau_p} \qquad (11)$$

where, τ_d and τ_p are the duration of dry and wet periods, respectively.

In application (1) described in Chapter 6, and in the calculation of regional residence times of SO_2 and sulfate discussed in Chapter 7, the precipitation rate P and the probability of a precipitation event f based on climatological data are used. On the other hand, in application (2) in

Chapter 6 where 24-hour average concentrations of SO_2 and sulfate are calculated, P and f are computed for every 12 hours at 81 weather stations and are interpolated for individual trajectory segments.

The actual values of the ratio (κ/χ) for SO_2 and sulfate are listed in Chapters 6 and 7.

4.2.2b Removal Due to Dry Deposition

Removal of SO_2 due to dry deposition has been reviewed in detail in our previous reports (Henmi et al., 1977 and 1978). Dry deposition of sulfate has not been studied extensively. The only known measurements of sulfate deposition velocity in the atmosphere yielded approximately 0.1 cm/sec (Engelman and Sehmel, 1976).

Realizing the difference of atmospheric conditions between daytime and nighttime, different values of dry deposition velocities are assigned for daytime and nighttime. Actual values of dry deposition velocities used for the concentration calculations of SO_2 and sulfate are described in Chapter 6.

4.2.2c Removal Due to Vertical Transport of Pollutants into the Free Atmosphere

Pollutants released into the mixing layer are dispersed into the free atmosphere by several processes, such as turbulent diffusion, convective activity, large-scale ascent from horizontal convergence and upgliding of warm air over cold air. The relative effectiveness of these processes depends on meteorological conditions. With improved knowledge of these processes we hope to be able to parameterize their impact on vertical mixing by chosing appropriate values for V_d, the vertical velocity through the top of the mixing layer. However, in the present models, we assume that $V_d = 0$.

4.2.2d Transformation of SO_2 to Sulfate

The following empirical relationship between the transformation rate and relative humidity is obtained:

$$K = 3.304\times10^{-4}\cdot\exp(0.063\cdot RH)\ hr^{-1} \tag{12}$$

K is the transformation rate of SO_2 to sulfate and RH is the relative humidity in percent. The derivation of this equation is described in Chapter 7.

The removal rate due to precipitation scavenging and the transformation rate of SO_2 to sulfate along trajectory segments are interpolated using the data of meteorological stations which are surrounding the midpoint of a trajectory segment. An interpolation routine from NCAR's Software Support Library was chosen and adapted in the model. The interpolation routine along with its attendant subroutines uses a given set of points and their coordinates (latitude and longitude) to set up a grid of triangles using those points as vertices (see Fig. 10). A linear interpolation from the triangle sides surrounding the midpoint of a trajectory segment is performed. If points outside the grid, (x_n, y_n), must be interpolated, this routine will extrapolate from the edge of the grid to those points.

4.2.4 Interpretation of Plume Concentrations to Grid Intersections

Models A and B are capable of calculating the average concentrations of sulfur dioxide and sulfate downstream from source areas over gridded regions. The procedure can be summarized as follows:

(i) The concentrations along trajectories are calculated using Eqs. (8) and (9). Latitudes and longitudes of endpoints of trajectory segments, and dispersion parameters are used as input data. Examples of the concentrations of SO_2 and sulfate along trajectories are shown in Figs. 11 to 13. In these figures, the source concentrations of SO_2 and of sulfate are assumed to be 30 $\mu g/m^3$ and 0 $\mu g/m^3$, respectively. Concentrations were calculated by Model B. They are different along different trajectories due to different values of dispersion parameters and of removal terms.

(ii) Each grid point over the region is examined as to whether or not it is located within the plume. If a grid point is located outside the plume, the concentration at that point is assigned the value 0. If a grid point is located within the plume, the concentrations based on Eqs. (8) and (9) are assigned to that point.
The criteria of determining whether or not grid points are located within the plume are discussed in the next section.

(iii) For each trajectory segment, step (ii) is repeated, and the values of concentrations at affected grid points are accumulated.

(iv) The calculations of concentrations for trajectories from different source areas are carried out repeating steps (i) and (ii). In Model B, the calculations of concentrations for trajectories of the winds in different layers are also conducted repeating steps (i) and (ii). The concentrations due to different sources and due to different trajectories are accumulated for each grid point.

(v) After step (iv) is completed, the average concentrations at grid points are calculated dividing the accumulated concentrations by N. Here N is defined as the number of days multiplied by the number of trajectories per day.

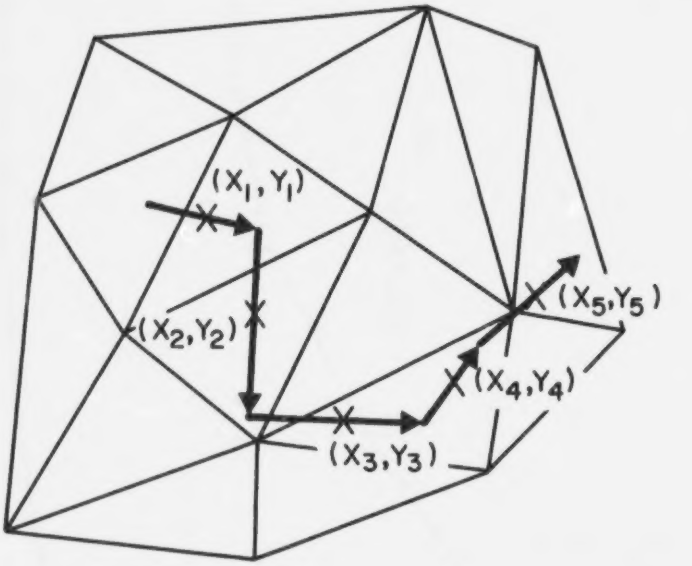
(X_1, Y_1)
(X_2, Y_2)
(X_3, Y_3)
(X_4, Y_4)
(X_5, Y_5)

Figure 10. Schematic diagram of determination of removal rate and transformation rate along a trajectory.

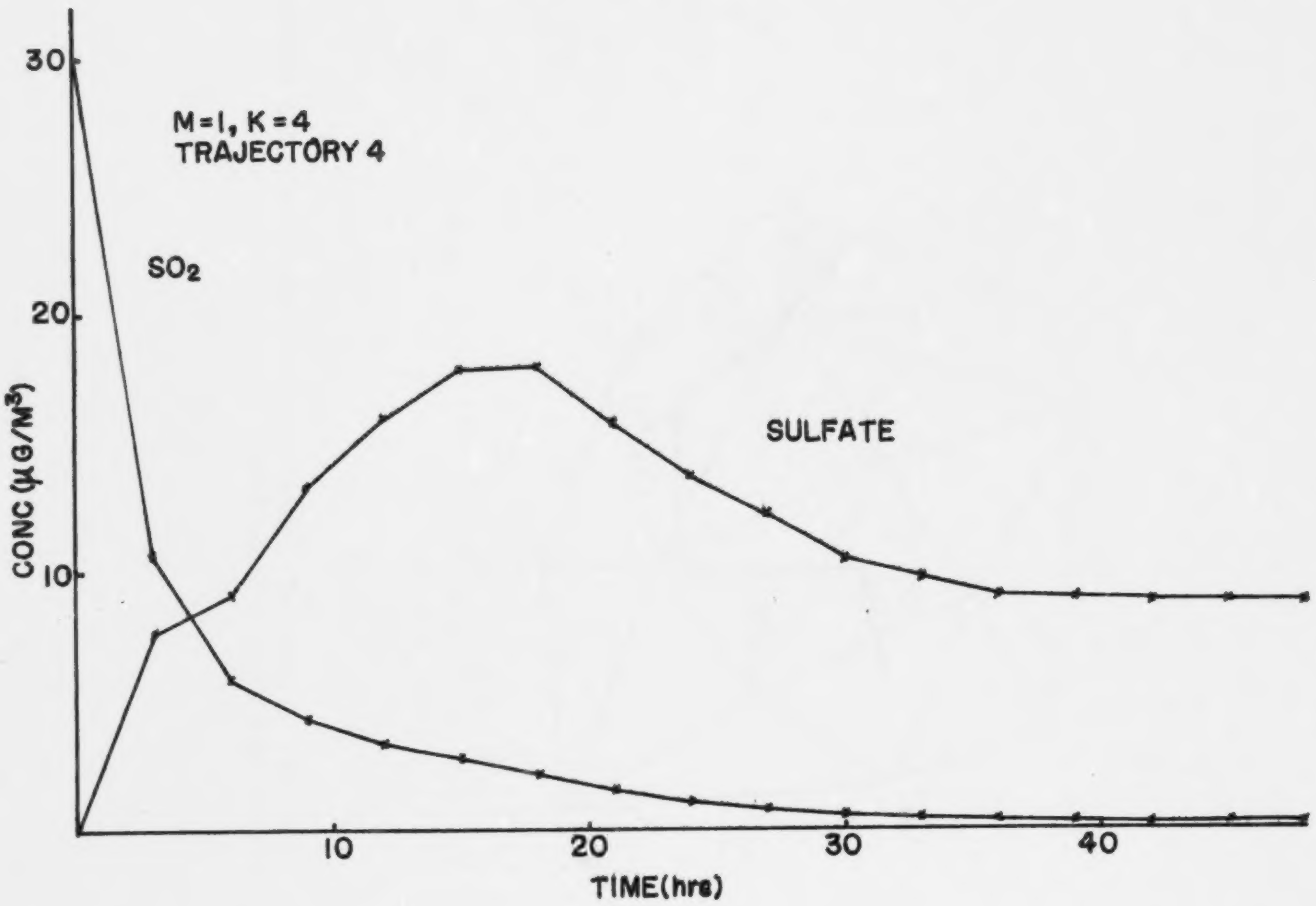

Figure 11. Example of the concentrations of SO_2 and sulfate along trajectory 1 for M = 1, K = 4.

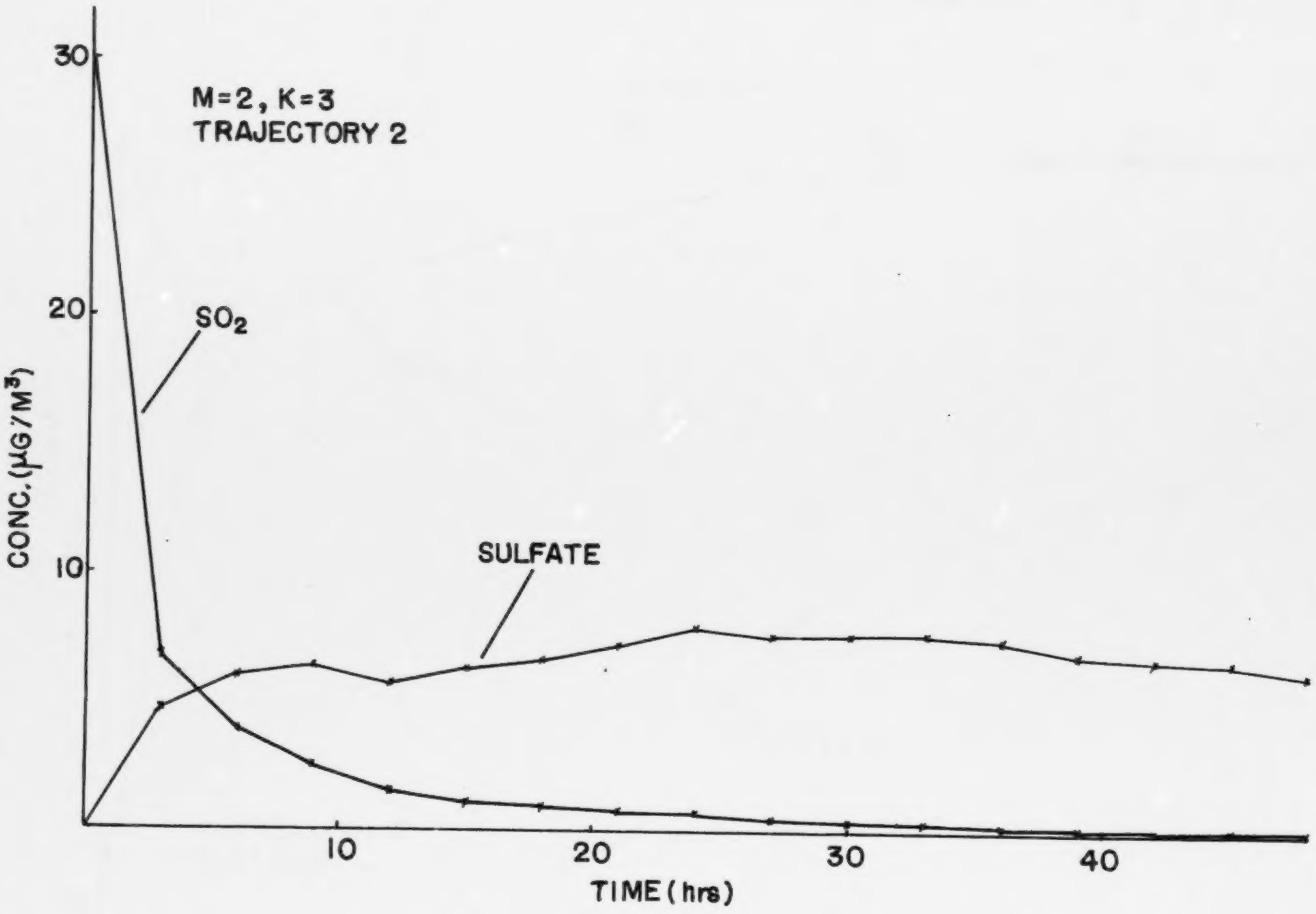

Figure 12. Example of the concentration of SO_2 and sulfate along trajectory 2 for M = 2, K = 3.

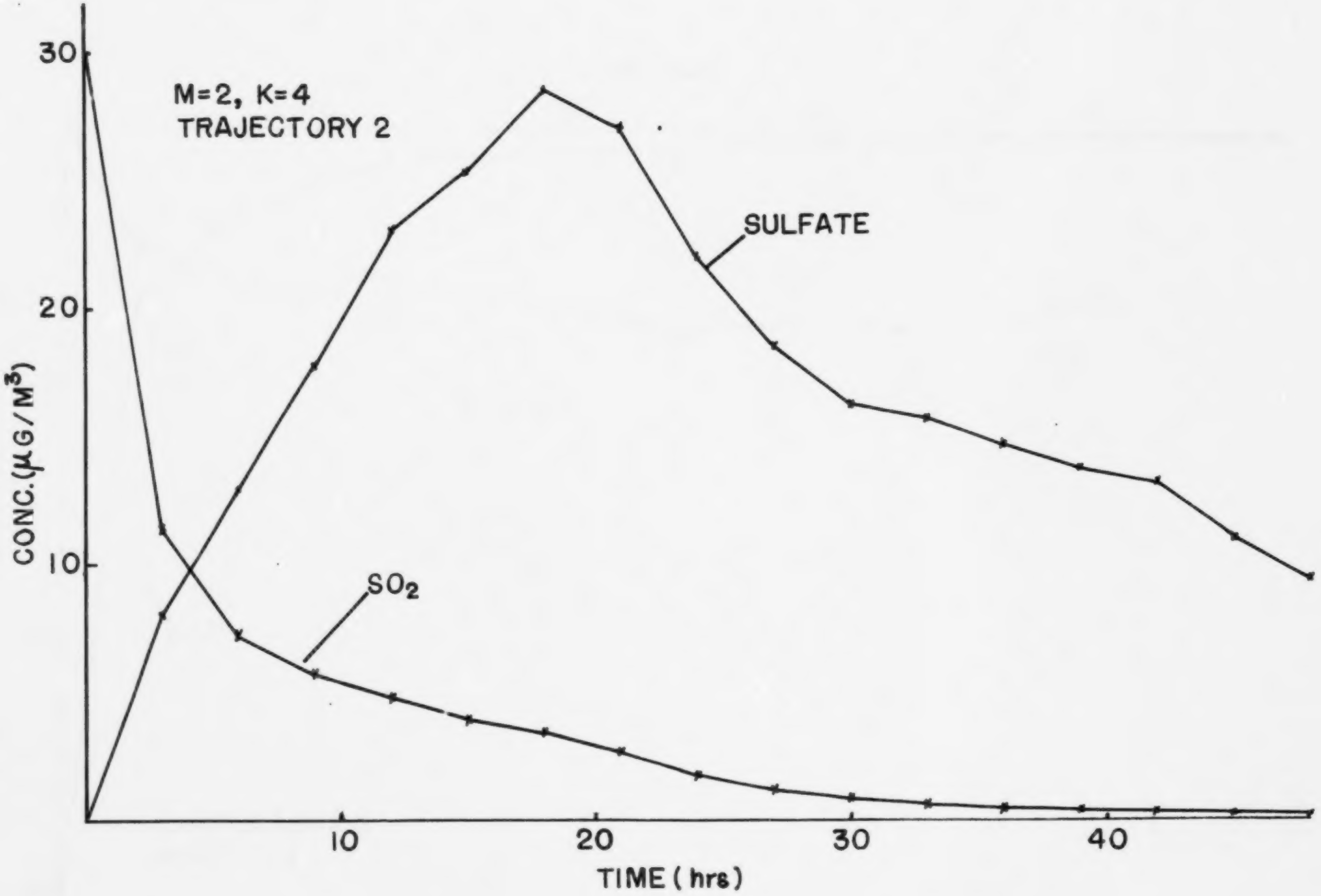

Figure 13. Example of the concentration of SO_2 and sulfate along trajectory 2 for M = 2, K = 4.

4.2.5 Criteria of Determining Locations of Grid Points Relative to the Plume

Referring to Fig. 14, the following parameters are defined:

θ_{n-1}, ψ_{n-1}: longitude and latitude of the endpoint of trajectory segment at time step n-1.

θ_n, ψ_n: longitude and latitude of the endpoint of trajectory segment at time step n.

d: the distance between $(\theta_{n-1}, \psi_{n-1})$ and (θ_n, ψ_n) and defined as

$$d = \sqrt{x^2 + y^2} \qquad \text{in nautical miles}$$

where

$$x = (\theta_{n-1} - \theta_n) \cdot \cos(\psi_{n-1} \cdot \pi/180) \cdot 60 \tag{13}$$

$$y = (\psi_n - \psi_{n-1}) \cdot 60. \tag{14}$$

t: the distance defined as

$$t = \sqrt{d^2 + \Sigma_h^2} \tag{15}$$

z: the distance between the grid point and the point $(\theta_{n-1}, \psi_{n-1})$

α: the angle defined as

$$\alpha = \tan^{-1} \frac{y}{x} \tag{16}$$

β: the angle defined as

$$\beta = \tan^{-1} \frac{\Sigma_h}{d} \tag{17}$$

γ: the angle extending between the line z and a latitude circle.

ε: the angle defined as

$$\varepsilon = \tan^{-1} \frac{d}{\Sigma_h} \tag{18}$$

δ_1: the angle defined as

$$\delta_1 = \alpha + \pi/2 \tag{19}$$

δ_2: the angle defined as

$$\delta_2 = \alpha + \frac{3}{2}\pi \tag{20}$$

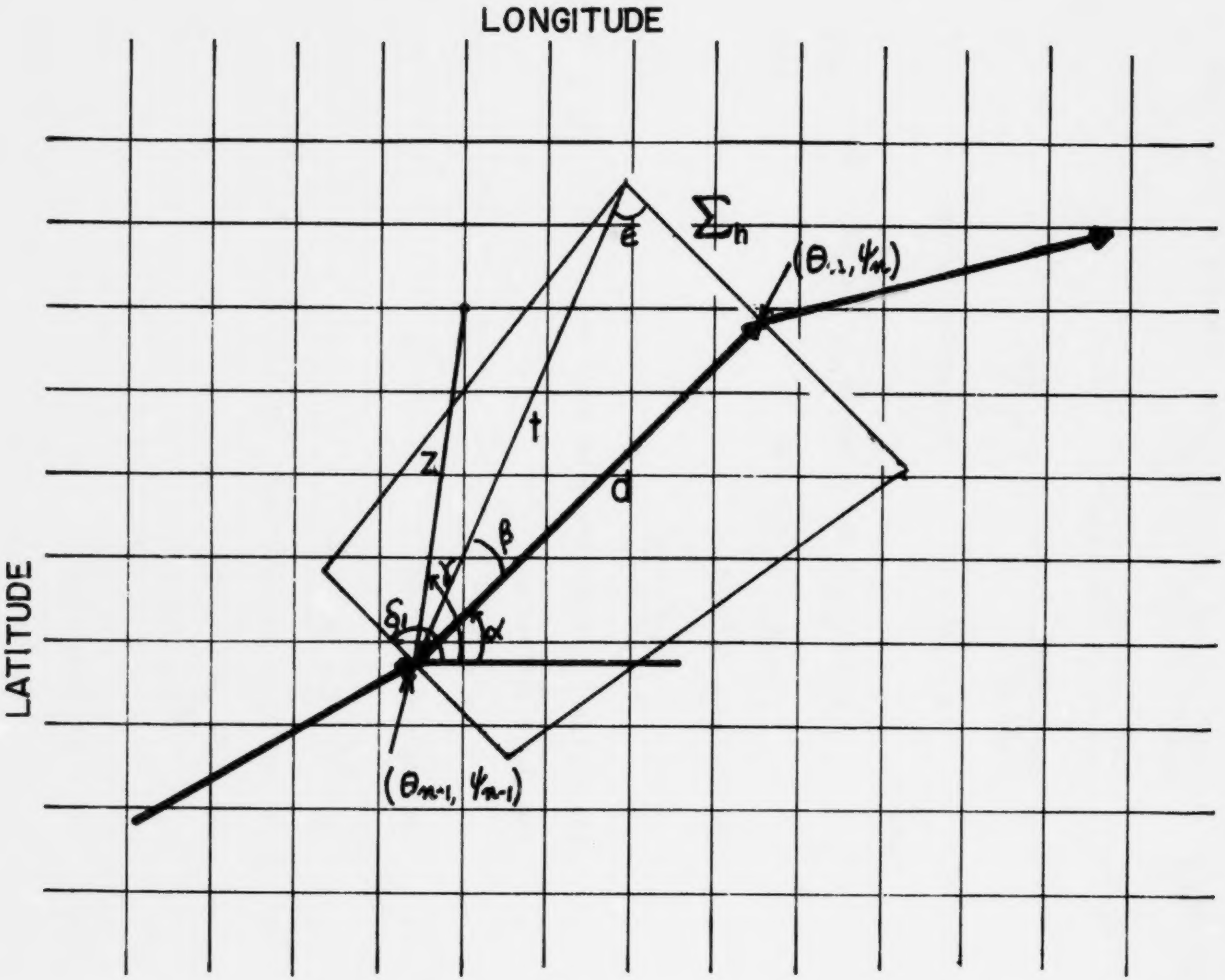
LONGITUDE
LATITUDE
Σ_n
ε
(θ_{n}, ψ_{n})
z
t
d
β
γ
δ_1
α
$(\theta_{n-1}, \psi_{n-1})$

Figure 14. Definition of angles α, β, σ, ε, δ_1 and δ_2; and distances d and t.

With these parameter definitions, the criteria for determining whether or not grid points are located within the trapezoidal plume segment are given such that z and γ must satisfy the following conditions:

[I] $\psi_n \geq \psi_{n-1}$ and $\theta_n \geq \theta_{n-1}$ (IJK = 1)

A. $\beta \geq \alpha$

1. $\alpha \leq \gamma \leq \alpha + \beta$

$$z \leq \frac{d}{\cos(\gamma-\alpha)}$$

2. $2\pi + (\alpha-\beta) \leq \gamma \leq 2\pi$

$$z \leq \frac{d}{\cos(\gamma-\alpha)}$$

3. $0 < \sigma < \alpha$

$$z \leq \frac{d}{\cos(\gamma-\alpha)}$$

4. $\alpha + \beta < \gamma \leq \delta_1$

$$z \leq t\,\frac{\cos(\varepsilon+\beta)}{\cos(\alpha-\gamma-\varepsilon)}$$

5. $\delta_2 \leq \gamma < 2\pi + (\alpha-\beta)$

$$a \leq t\,\frac{\cos(\varepsilon+\beta)}{\cos(\gamma-\alpha-\varepsilon)}$$

B. $\beta < \alpha$

1. $\alpha - \beta \leq \gamma \leq \alpha + \beta$

$$z \leq \frac{d}{\cos(\alpha-\gamma)}$$

2. $\alpha + \beta < \gamma \leq \delta_1$

$$z \leq t\,\frac{\cos(\varepsilon+\beta)}{\cos(\alpha-\gamma-\varepsilon)}$$

3. $\delta_2 \leq \gamma < 2\pi$

$$z \leq t\,\frac{\cos(\varepsilon+\beta)}{\cos(\gamma-\alpha-\varepsilon)}$$

4. $0 \leq \gamma \leq \alpha - \beta$

$$z \leq t\,\frac{\cos(\varepsilon+\beta)}{\cos(\gamma-\alpha-\varepsilon)}$$

[II] $\psi_n \geq \psi_{n-1}$ and $\theta_n > \theta_{n-1}$ (IJK = 2) and

[III] $\psi_n < \psi_{n-1}$ and $\theta_n < \theta_{n-1}$ (IJK = 3)

1. $\alpha - \beta \leq \gamma \leq \alpha + \beta$

$$z \leq \frac{d}{\cos(\alpha-\gamma)}$$

2. $\delta_2 \leq \gamma < \alpha - \beta$

$$z \leq t\,\frac{\cos(\varepsilon+\beta)}{\cos(\gamma-\varepsilon-\alpha)}$$

3. $\alpha + \beta < \gamma \leq \delta_1$

$$z \leq t\,\frac{\cos(\varepsilon+\beta)}{\cos(\gamma-\varepsilon-\alpha)}$$

[IV] $\psi_n < \psi_{n-1}$ and $\theta_n \leq \theta_{n-1}$ (IJK = 4)

A. $\alpha + \beta \geq 2\pi$

1. $\alpha - \beta \leq \gamma \leq 2\pi$

$$z \leq \frac{d}{\cos(\alpha-\gamma)}$$

2. $0 < \gamma \leq \alpha + \beta - 2\pi$

$$z \leq \frac{d}{\cos(\alpha-\gamma)}$$

3. $\delta_1 \geq \gamma \; \alpha + \beta - 2\pi$

$$z \leq t \frac{\cos(\varepsilon+\beta)}{\cos(\alpha-\varepsilon-\gamma)}$$

4. $\delta_2 \leq \gamma < \alpha - \beta$

$$z \leq t \frac{\cos(\varepsilon+\beta)}{\cos(\gamma-\alpha-\varepsilon)}$$

B. $\alpha + \beta < 2\pi$

1. $\alpha - \beta \leq \gamma \leq \alpha + \beta$

$$z \leq \frac{d}{\cos(\alpha-\gamma)}$$

2. $\delta_2 \leq \gamma < \alpha - \beta$

$$z \leq t \frac{\cos(\varepsilon+\beta)}{\cos(\gamma-\alpha-\varepsilon)}$$

3. $\alpha + \beta < \gamma \leq 2\pi$

$$z \leq t \frac{\cos(\varepsilon+\beta)}{\cos(\alpha-\gamma-\varepsilon)}$$

4. $0 < \gamma \leq \delta_1$

$$z \leq t \frac{\cos(\varepsilon+\beta)}{\cos(\alpha-\gamma-\varepsilon)}$$

4.3 OUTPUT OF MODELS

Output parameters calculated for each grid point by the models are as follows:

Program A

1. Average concentration of SO_2 ($\mu g/m^3$)
2. Average concentration of sulfate ($\mu g/m^3$)
3. Deposition amount of SO_2 (Kg/Km^2)
4. Deposition amount of sulfate (Kg/Km^2)

Program B

1. Average concentration of SO_2 at the surface ($\mu g/m^3$)
2. Average concentration of SO_2 above the nighttime stable layer height ($\mu g/m^3$)
3. Average concentration of sulfate at the surface ($\mu g/m^3$)
4. Average concentration of sulfate above the nighttime stable layer height ($\mu g/m^3$)
5. Total deposition amount of SO_2 (Kg/Km^2) due to dry deposition and precipitation scavenging
6. Total deposition amount of sulfate (Kg/Km^2) due to dry deposition and precipitation scavenging
7. Deposition amount of SO_2 due to precipitation (Kg/Km^2)
8. Deposition amount of sulfate due to precipitation (Kg/Km^2)

Here, the deposition amounts of SO_2 and sulfate on the surface are calculated from $(V_{g1}+fV_{s1})xC_1$ and $(V_{g2}+fV_{s2})xC_2$. In Model B, the deposition amounts due to precipitation only are also calculated.

4.4 PRELIMINARY COMPARISON OF THE OUTPUT OF MODEL A AND MODEL B

In order to compare the performances of Models A and B, the following preliminary calculations were conducted. The source was assumed to be located at 38.4°N and 90.1°W. The region between 30°N and 45°N and between 90°W and 105°W was considered. The source concentrations of SO_2 and sulfate were assumed as 30 μg/m^3 and 0 μg/m^3, respectively.

It was also assumed that no precipitation fell over the area. Realizing the difference of atmospheric conditions between daytime and nighttime, different values of removal terms were assigned for these times. The following values were used for this calculation.

	Daytime		Nighttime	
V_{g1}	2	cm/sec	1	cm/sec
V_{g2}	0.2	cm/sec	0.1	cm/sec
K	$6x10^{-6}$	sec^{-1}	$3x10^{-6}$	sec^{-1}
V_{s1}	0	cm/sec	0	cm/sec
V_{s2}	0	cm/sec	0	cm/sec
V_{d1}	0	cm/sec	0	cm/sec
V_{d2}	0	cm/sec	0	cm/sec

The calculation of trajectories and dispersion parameters were made using observed wind data supplied by NOAA's Air Resources Laboratory at Silver Spring, Maryland. The calculations were conducted for two days, from May 1, 1974 to May 2, 1974. Trajectories were initiated every 6 hours. The daytime mixing height H_2 was assumed to be 2000 m, and the nighttime mixing height H_1 was assumed to be 500 m. For this test-run the background concentrations of both SO_2 and sulfate in the region under consideration were assumed to be zero.

Trajectories and dispersion parameters for this example have been shown in Figs. 2 and 3 and Figs. 4 to 7, respectively.

The output of Model A is shown in Figs. 15 to 18. Figures 19 to 24 give the output of Model B. It can be seen from a comparison of these figures that SO_2 concentrations obtained from both Model A and Model B are

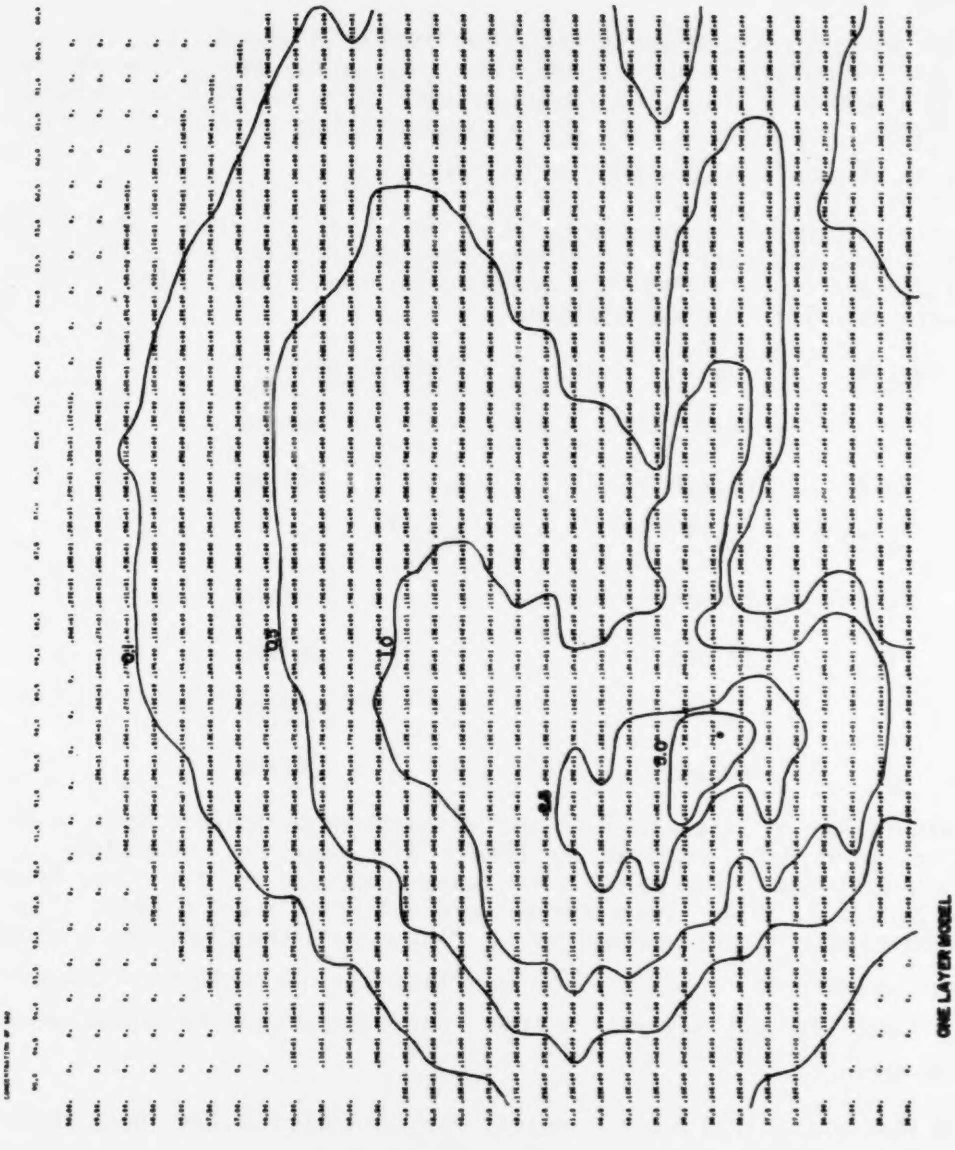

Figure 15. Distribution of average concentrations of SO_2 ($\mu g/m^3$). Model A.

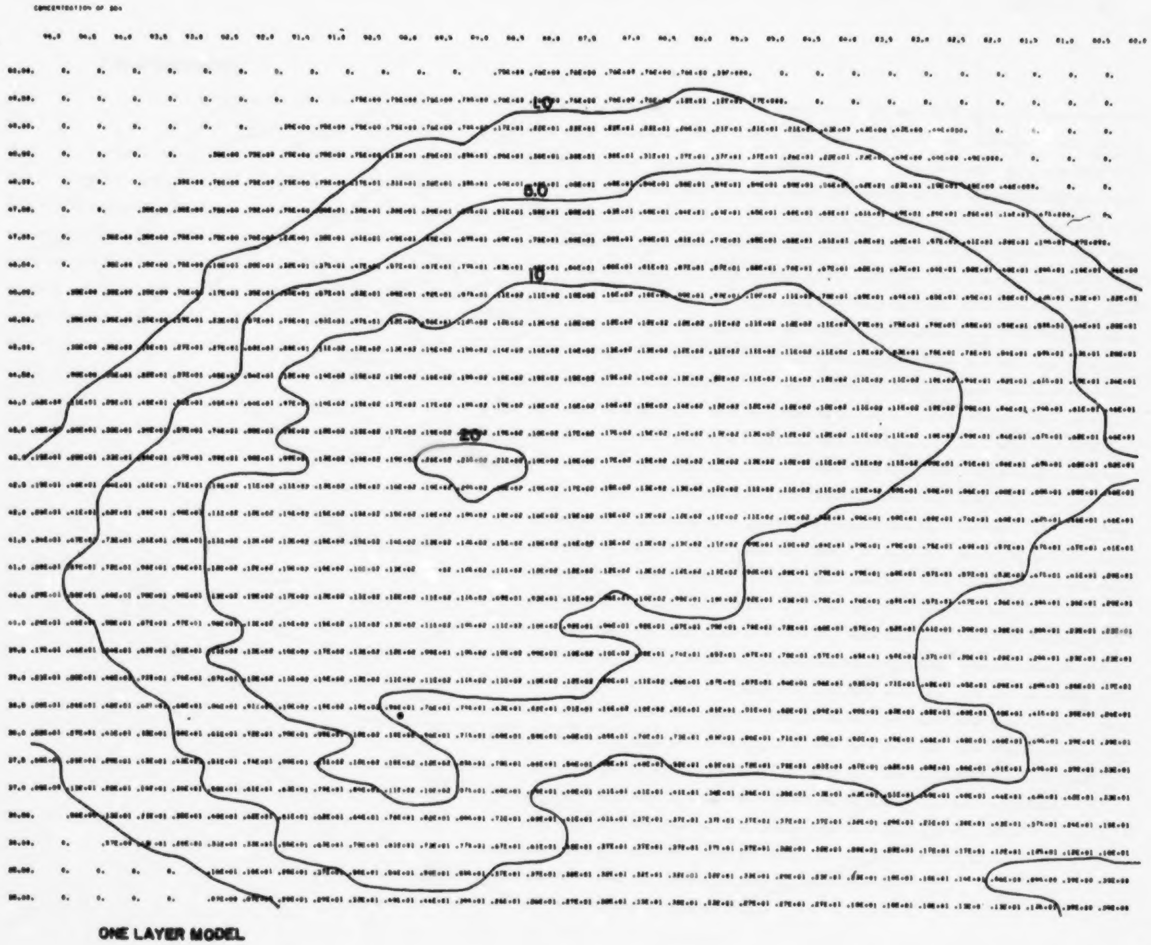
CONCENTRATION OF SO4
1.0
6.0
10
20
ONE LAYER MODEL

Figure 16. Distribution of average concentrations of sulfate ($\mu g/m^3$). Model A.

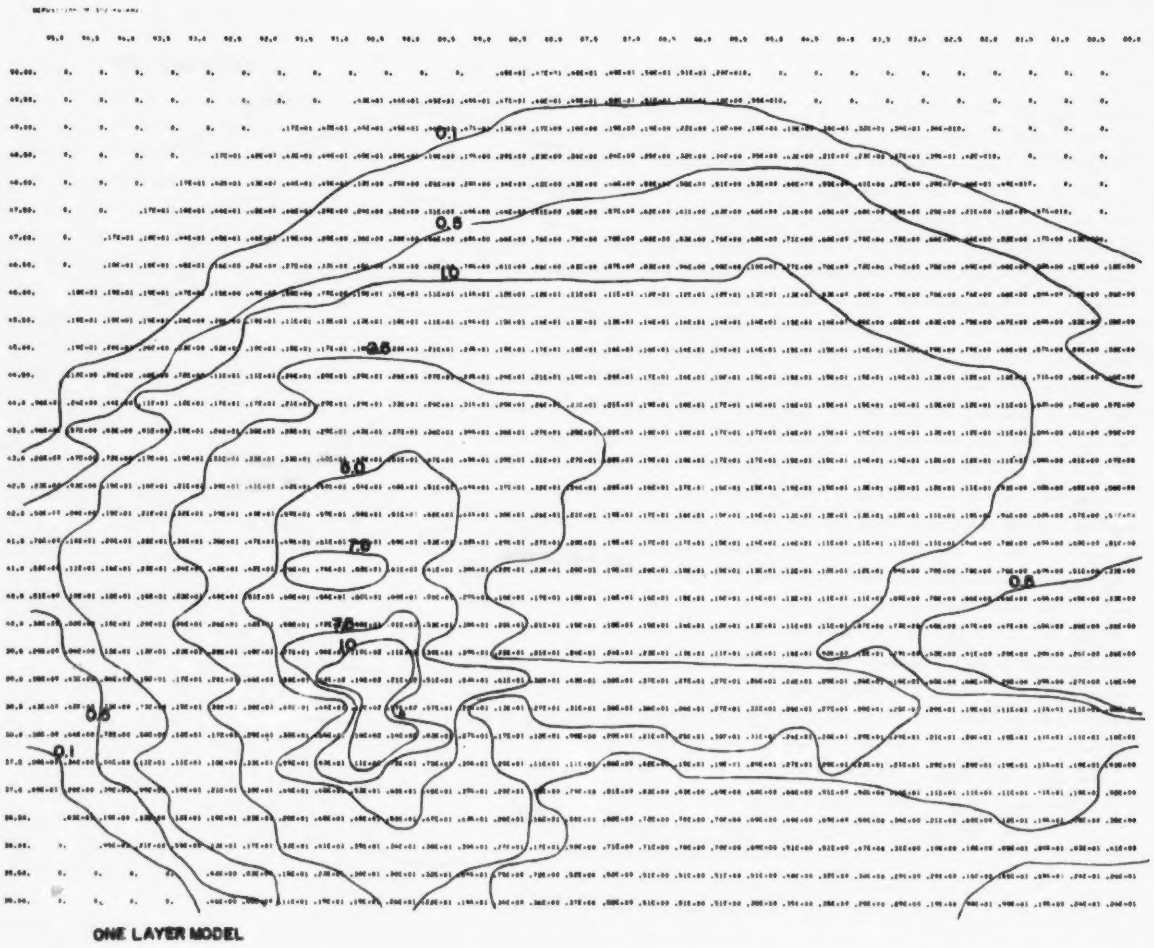

Figure 17. Distribution of deposition amounts of SO_2 (Kg/Km^2). Model A.

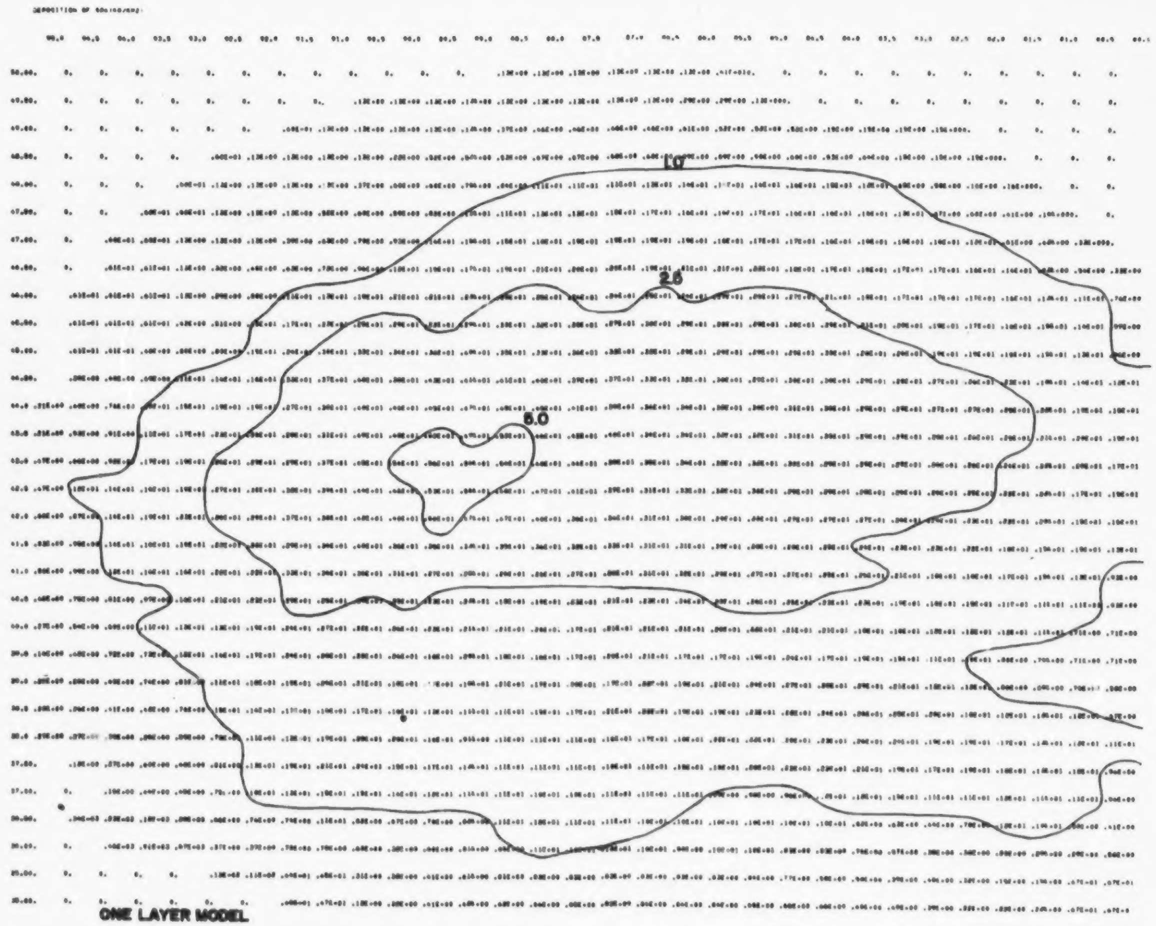
1.0
2.5
5.0
ONE LAYER MODEL

Figure 18. Distribution of deposition amounts of sulfate (Kg/Km^2). Model A.

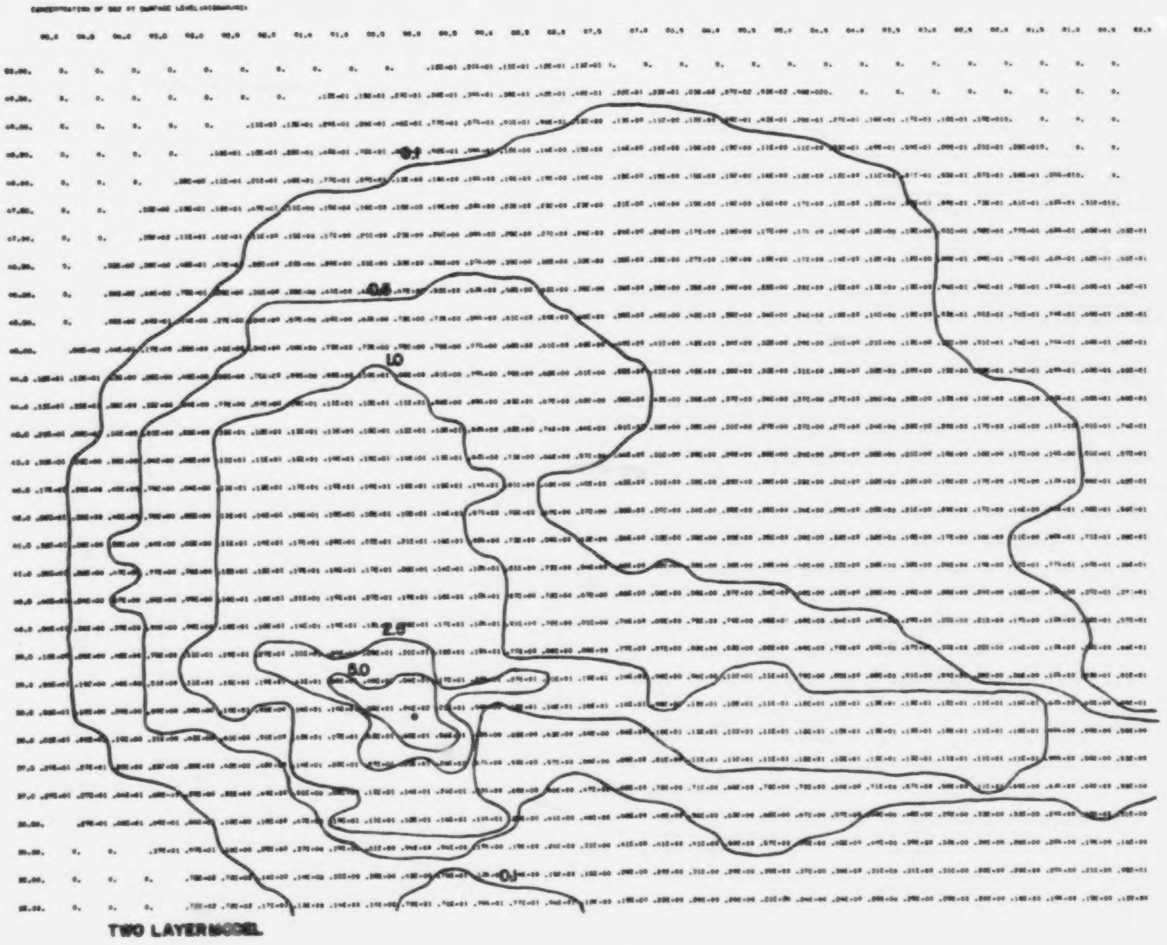

Figure 19. Distribution of average concentrations of SO_2 at the surface ($\mu g/m^3$). Model B.

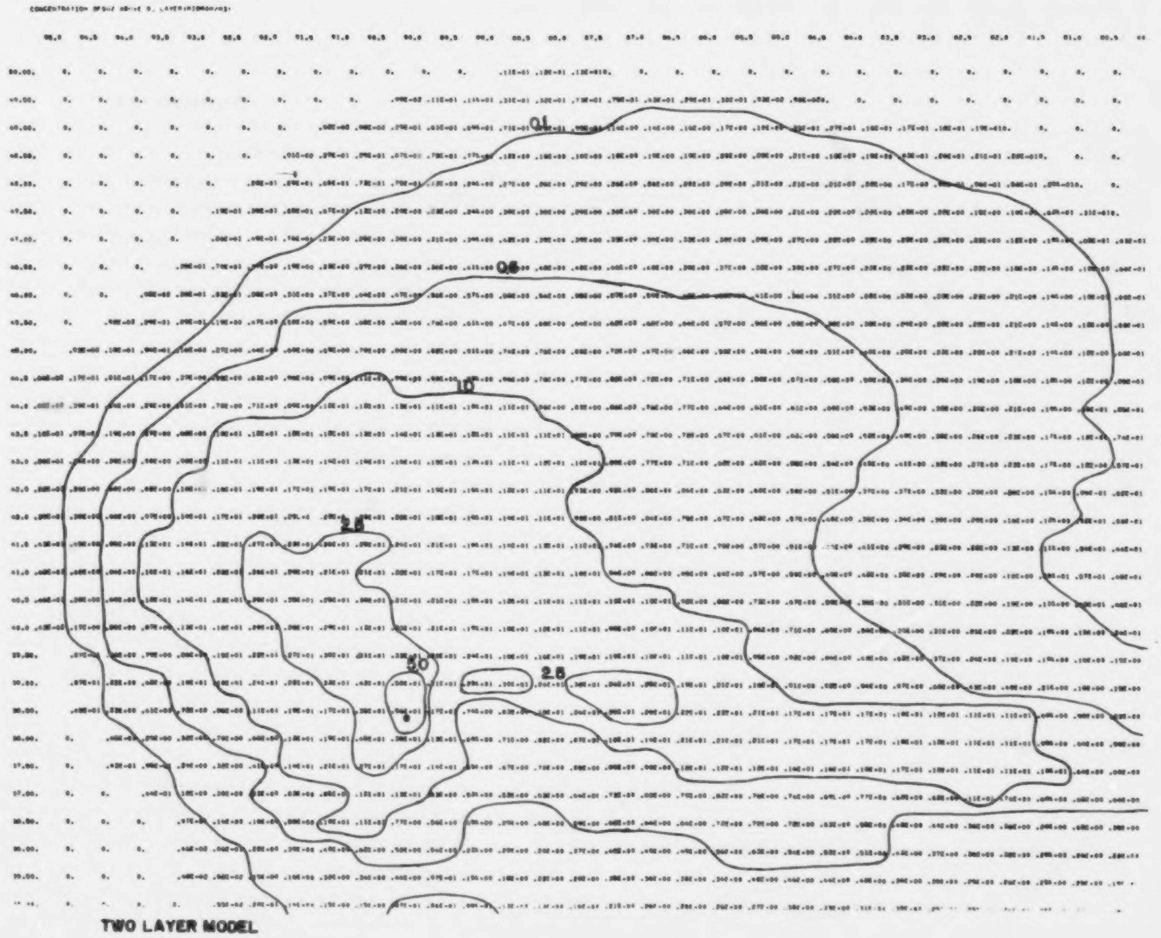
0.1
0.5
1.0
2.5
5.0
2.5
TWO LAYER MODEL

Figure 20. Distribution of average concentrations of SO_2 above the nighttime mixing height ($\mu g/m^3$). Model B.

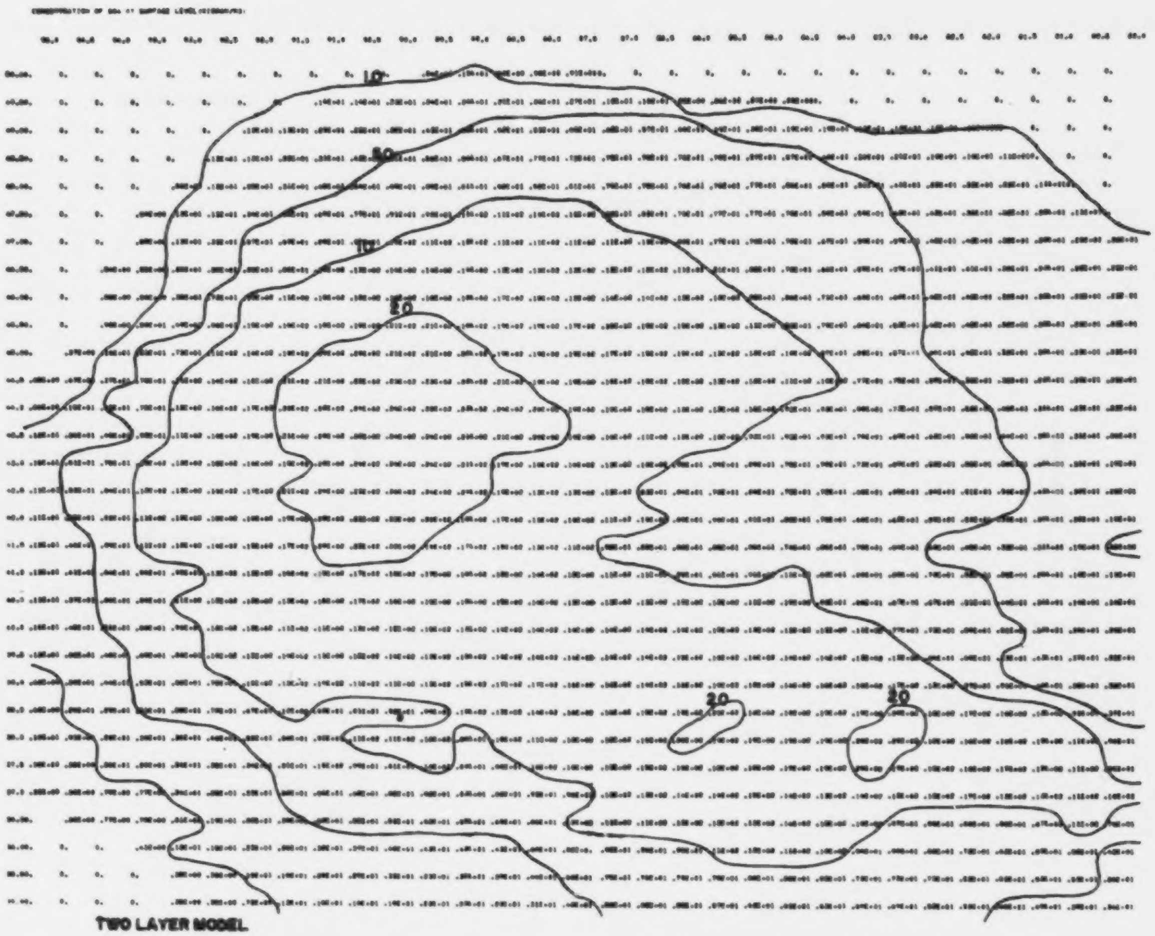
10
20
20
TWO LAYER MODEL

Figure 21. Distribution of average concentrations of sulfate at the surface ($\mu g/m^3$). Model B.

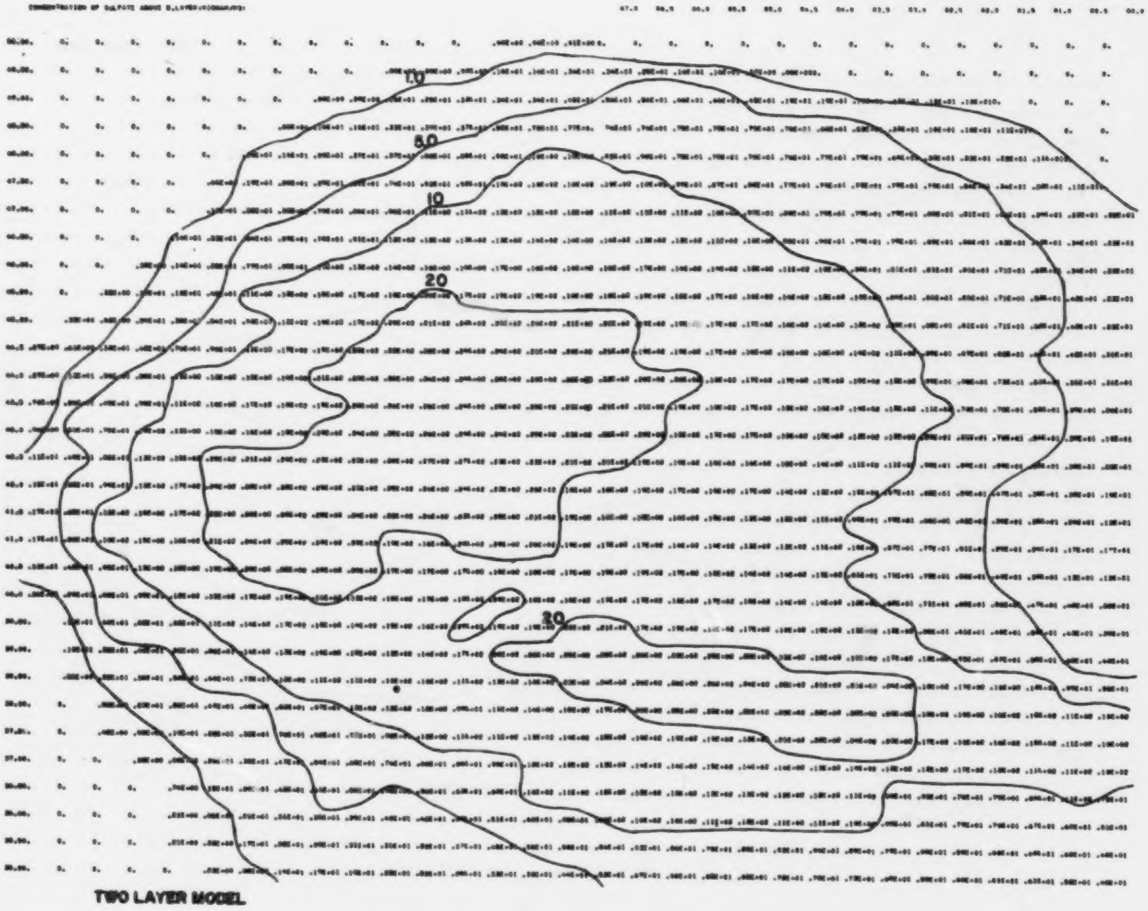

Figure 22. Distribution of average concentrations of sulfate above the nighttime boundary layer (μg/m^3). Model B.

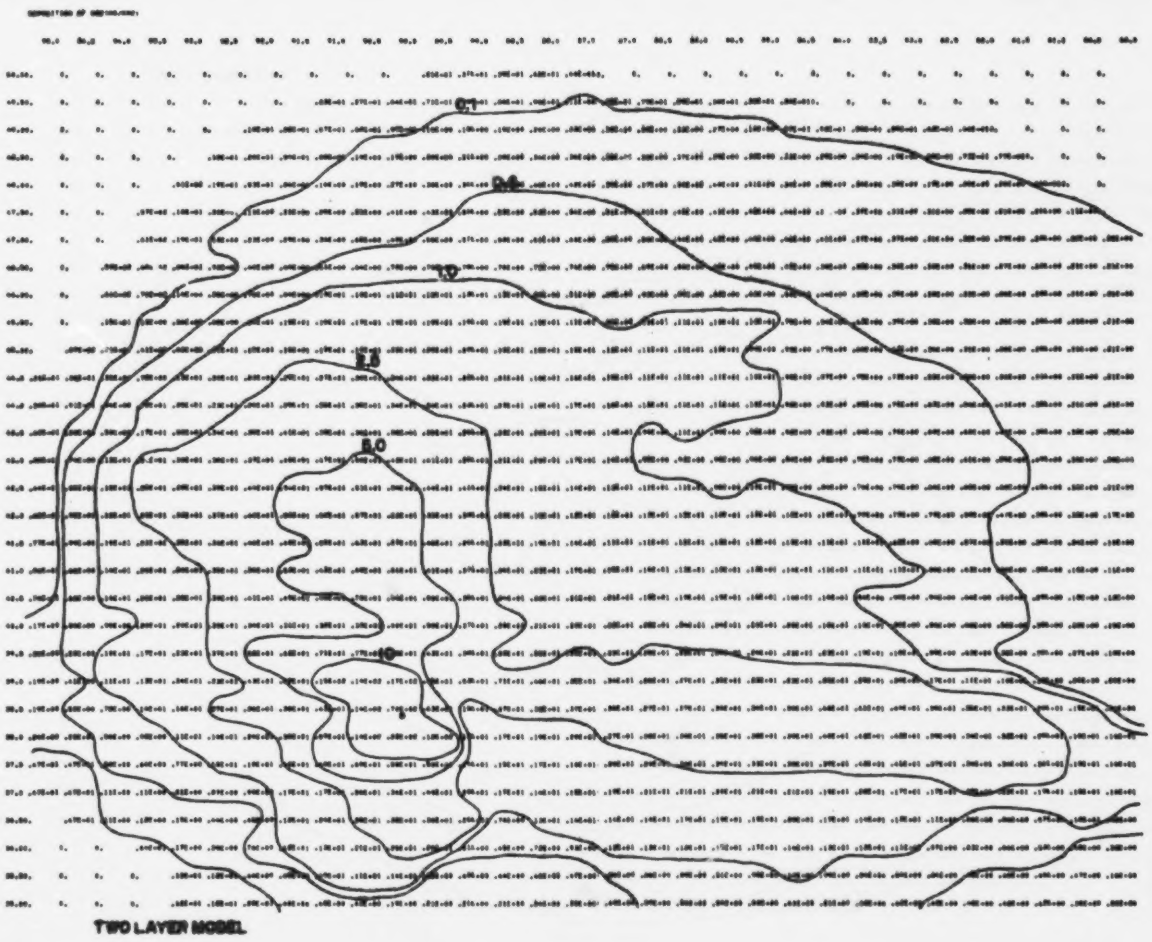

Figure 23. Distribution of deposition amounts of SO_2 (Kg/Km^2). Model B.

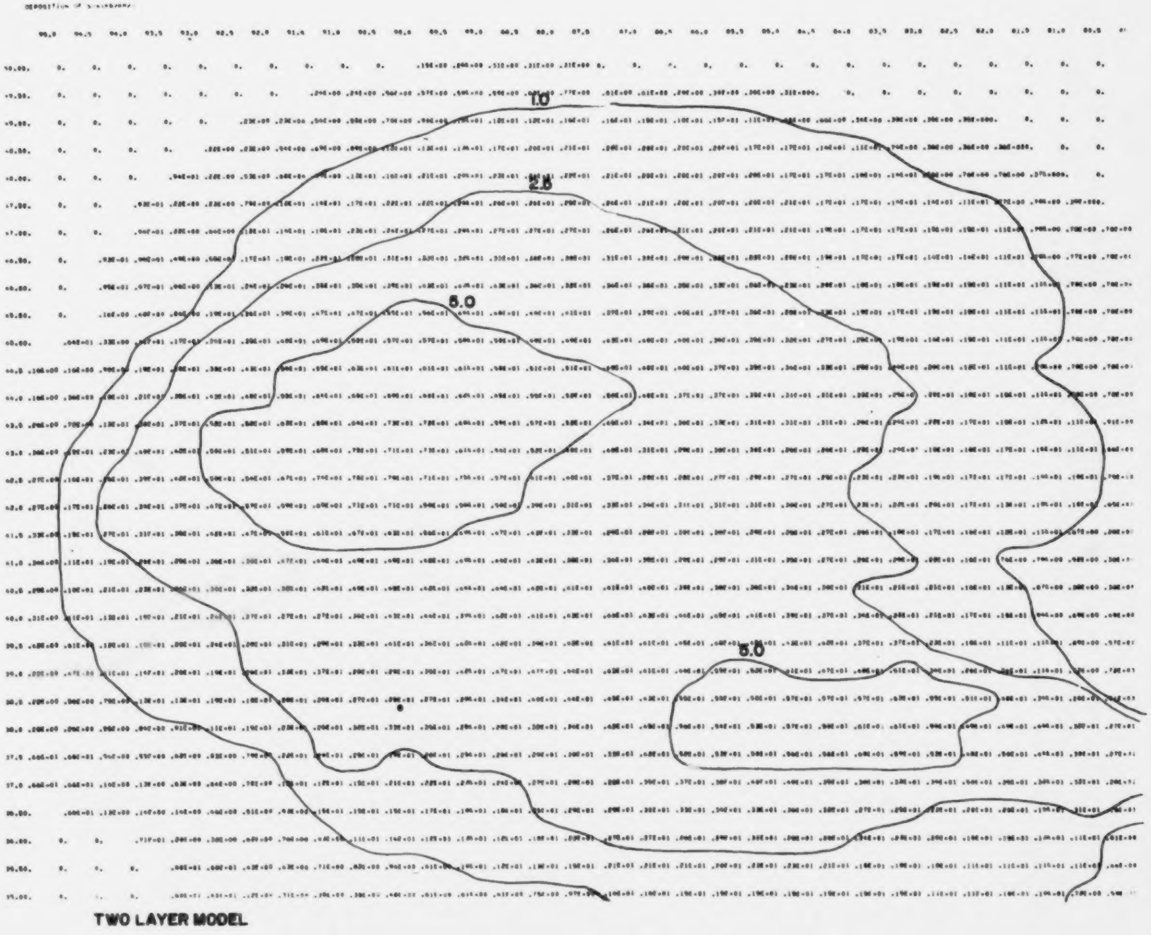
1.0
2.5
5.0
5.0
TWO LAYER MODEL

Figure 24. Distribution of deposition amounts of sulfate (Kg/Km^2). Model B.

very similar. However, the sulfate distribution calculated by Model A shows different features from that calculated by Model B. Because of the preliminary nature of these test-runs, conclusions from the above results will not be drawn.

The computing time required by Model B is about three times longer than that required by Model A. Interpolation schemes of concentrations along trajectory into grid points use more than 90 percent of the computing time. The computing time is proportional to the number of grid points, number of sources, number of trajectories and number of days for which calculations are carried out.

CHAPTER 5

DETAILED STRUCTURE OF THE MODELS

In order to calculate the distributions of SO_2 and sulfate concentrations due to multiple sources, Model A as well as Model B are divided into two major routines, a trajectory program and a concentration program. The present versions of either Model A or Model B can calculate the concentrations due to five sources at a time. The concentrations due to more than five sources can be calculated by applying the model repeatedly.

Both models can be used to calculate the average concentrations of SO_2 and sulfate for time periods longer than 24 hours.

5.1 TRAJECTORY PROGRAM

5.1.1 Flow Charts

Flow charts of the trajectory calculation routines for Model A and Model B are shown in Figs. 25 and 26.

5.1.2 Description

The function of the trajectory program is to use upper-air multi-level wind speed and direction observations from a randomly distributed network of reporting stations to compute trajectories, dispersion parameters and other parameters along the trajectories within layers of specified thickness.

The major input parameters to the program are latitude and longitude values of stations, wind direction and speed data as a function of height from rawinsonde observations. These data are on magnetic tapes.

The major output consists of latitude and longitude values of the end-points of trajectory segments, mean wind speeds, dispersion parameters and other parameters which have been described in the previous chapter.

Model A

The program of trajectory calculations consist of a main program and nine subroutines, plus seven subroutines which are used in the transmittal of information from the data.

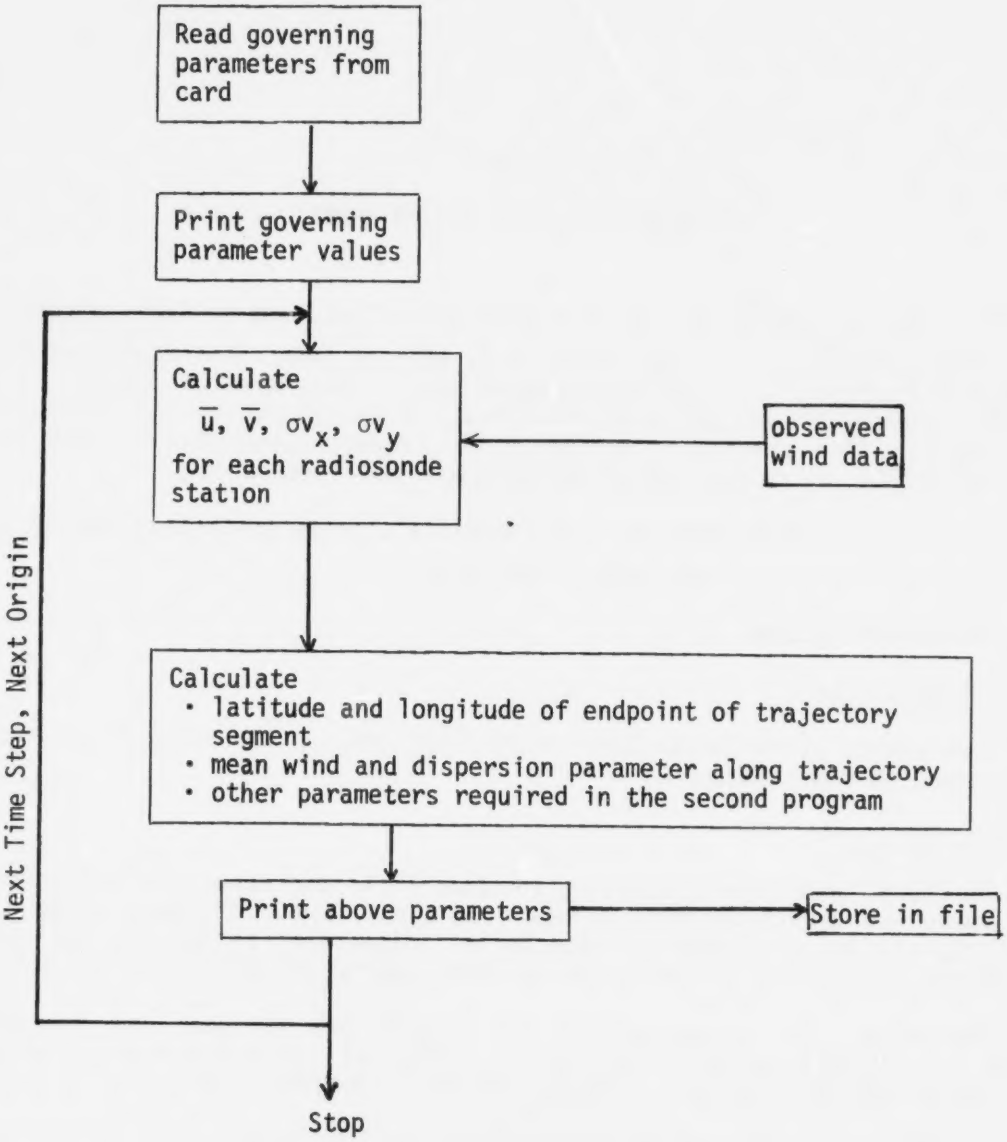
Read governing parameters from card
Print governing parameter values
Calculate
$\overline{u}$, $\overline{v}$, σv_x, σv_y
for each radiosonde station
observed wind data
Calculate
• latitude and longitude of endpoint of trajectory segment
• mean wind and dispersion parameter along trajectory
• other parameters required in the second program
Print above parameters
Store in file
Next Time Step, Next Origin
Stop

Figure 25. Flow diagram of trajectory program of Model A.

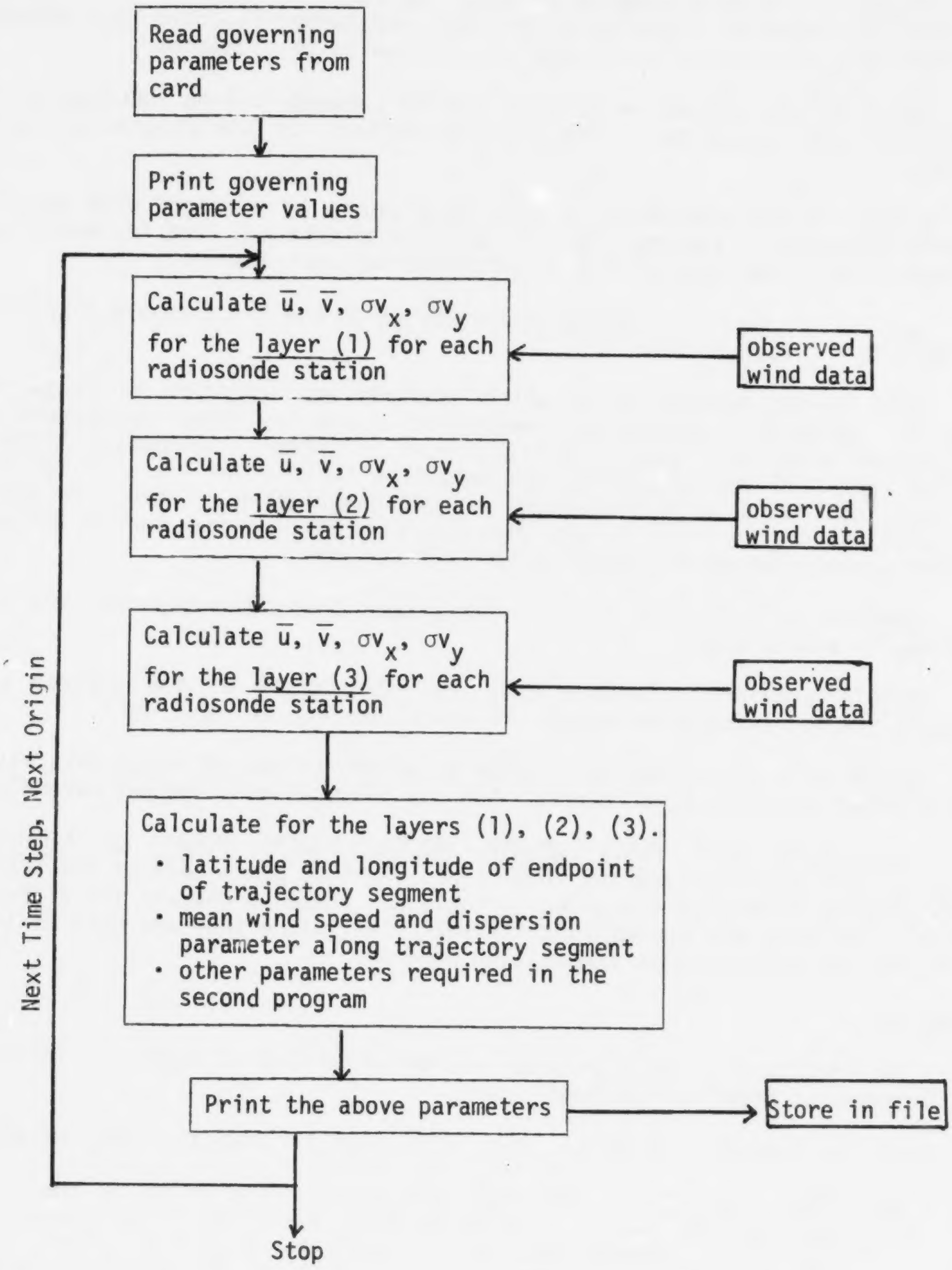
Read governing parameters from card
Print governing parameter values
Calculate $\overline{u}$, $\overline{v}$, σv_x, σv_y for the layer (1) for each radiosonde station
observed wind data
Calculate $\overline{u}$, $\overline{v}$, σv_x, σv_y for the layer (2) for each radiosonde station
observed wind data
Calculate $\overline{u}$, $\overline{v}$, σv_x, σv_y for the layer (3) for each radiosonde station
observed wind data
Calculate for the layers (1), (2), (3).
• latitude and longitude of endpoint of trajectory segment
• mean wind speed and dispersion parameter along trajectory segment
• other parameters required in the second program
Print the above parameters
Store in file
Next Time Step, Next Origin
Stop

Figure 26. Flow diagram of trajectory program of Model B.

TRAJET is the main program in which the loops of number of days, number of origins, number of trajectories per day, and number of trajectory segments are defined. The output parameters are written in this program.

INPUT is the subroutine to read control parameters from input cards and to define other parameters. The input parameters for the program are given in Table 1.

DTABKO is the subroutine to make data blocks of averaged wind and dispersion parameters, calling RDAVO in which wind data are read in, and x- and y-components of the mean wind are calculated for each station.

AWIND is called from RDAVO to average winds and to calculate dispersion parameters for each station.

DISO is the subroutine in which latitude and longitude of trajectory segments, dispersion parameters, mean wind speeds and other parameters are calculated using the data block calculated in DTABKO. Subroutine ITSIW is called from DISO and calculates the weighting factors and the contributions of individual data to a trajectory segment calculation. Subroutine XSZ is to calculate angles α and β, and distance parameters t and d which are used in the second program of concentration calculations.

KKMM is the subroutine to determine proper trajectory segments, and time and day in a data block.

ALTDTA provides alternate data for the output of the program when outputs are not calculated because of unavailability of input data.

CLSTM is a subroutine to provide an alternate set of input data within the closest synoptic time interval for the calculation of output parameters.

Subroutines BOUT, POSTP, RDDATE, RDSTHD, RDWIND, RDDATA and ATAPE are used to read the data from the input tapes. Output parameters of the trajectory program of Model A are given in Table 2. These parameters for different sources (origin) are stored in different files, since they are used as input data for the concentration computation program.

Model B

The structure of this program is similar to that of Model A. The major differences of Model B from Model A are:

(i) A temporary file to store wind data for repeated use is added.

(ii) Subroutines DISO2 and DISO3 are added. The roles of these subroutines are similar to those of DISO, but DISO2 is for the wind of the layer between the surface and the nighttime stable layer height, and DISO3 is for the wind of the layer between the nighttime stable layer height and the daytime mixing height.

TABLE 1. INPUT PARAMETERS FOR THE TRAJECTORY PROGRAM OF MODEL A

Card No.	Parameter Names	Definition	
1	NO	Number of origins	
	NDY	Number of days for which computations are desired	
2~6	OID	Name of origins (sources)	
	OLAT	Latitude of origin (sources)	
	OLON	Longitude of origin (sources)	
7~11	WIOROT	Width of sources	
12	IBDY	Day	of the beginning of computation
	IMO	Month	
	IBYR	Year	
	IHOUR	Hour	
	IBMO	Month in logical card	
13	IDIR	Direction of trajectory, forward (FORW)	
	NDYDUR	Duration in days	
14	NDYDTA	Number of days of wind input data	
15	WTYPE	Type of wind input data, observed (OBS)	
16	DTABT	Top latitude	of boundaries for observed wind input data
	DTABB	Bottom latitude	
	DTABL	Left longitude	
	DTABR	Right longitude	
17	LBAAT	Base	of transport layer in meters
	LTAAT	Top	
18	ALATT	Top	boundaries for map
	ALATB	Bottom	
	ALONL	Left	

TABLE 2. OUTPUT PARAMETERS OF PROGRAM A

Parameter Names	Definition
TSLAT	Latitude of the endpoint of trajectory segment
TSLON	Longitude of the endpoint of trajectory segment
UBAR	Mean wind speed along trajectory segment
SPREAD	Dispersion parameter
ALPHA	Angle α defined in Figure 8
BETA	Angle β defined in Figure 8
T	Distance t defined in Figure 8
R2	Distance d defined in Figure 8
IJK	Direction indicator
ICNT SICNT	Parameters necessary for mapping

(iii) Subroutine CONVER is added in which output parameters are replaced by differently-named parameters.

(iv) The main program TRAJET becomes longer to calculate simultaneously four trajectories and parameters along these trajectories. Governing input parameters for Model B are read in a subroutine INPUT and are shown in Table 3.

Output parameters of Model B are given in Table 4. Since trajectories of mean winds in three different layers are computed, there are four trajectories for two-day periods. Output parameters for each trajectory are stored separately in a different file.

5.2 CONCENTRATION CALCULATION PROGRAM

5.2.1 Flow Charts

Flow charts of the concentration calculation programs of Models A and B are shown in Figs. 27 and 28.

5.2.2 Description

The function of the concentration calculation program is to use input data generated in the trajectory program for the computation of average concentrations and deposition amounts of SO_2 and sulfate over gridded areas.

Model A

The program consists of a main program and two subroutines.

In the main program TRAJET, governing parameters which have been given originally in the trajectory program are transferred into the concentration calculation program. Input data generated in the trajectory program are also read from files in the main program.

Subroutine CONCAL is the major part of the concentration calculation program, in which the concentration calculations along trajectories and interpolations of the plume concentrations to grid points are made.

Subroutine REMOVE is called from CONCAL to give the values of removal terms according to the number of loops which represent the time of day.

Input data which must be read in from cards are source concentrations of SO_2 and of sulfate, and the width of the source. These data and are shown in Table 5.

Model B

In addition to the main program and two subroutines used in Model A, Model B calls upon the subroutines DETCON, PRECIP, TRIANG, CONHUL, BADGET, TMESH, TMESHI, SORTI, PVEC, and STEST, and the functions TRINTR and LTEST.

TABLE 3. INPUT PARAMETERS FOR THE TRAJECTORY PROGRAM OF PROGRAM B

Card No.	Parameter Names	Definition	
1	NO	Number of sources	
	NDY	Number of days for which computations are desired	
2~6	OID	Name	
	OLAT	Latitude	of sources
	OLON	Longitude	
	WIORT	Width	
	$ERSO_2$	Emission rate of SO_2	from sources
	ERSUL	Emission rate of sulfate	
4	IBDY	Day	of the beginning of computation
	IMO	Month	
	IBYR	Year	
	IHOUR	Hour	
	IBMO	Month in logical cord	
5	TDIR	Direction of trajectory, forward (FORW)	
	NDYDUR	Duration in days	
6	NDYDTA	Number of days of wind input data	
7	WTYPE	Type of wind input data, observed (OBS)	
8	DTABT	Top latitude	of boundaries for observed wind input data
	DTABB	Bottom latitude	
	DTABL	Left longitude	
	DTABR	Right longitude	
9	LBAAT	Bottom of mixing height	
	LTAAT	Daytime mixing height	
	LMAAT	Nighttime mixing height	
10	ALATT	Top	boundaries for map
	ALATB	Bottom	
	ALONL	Left	

TABLE 4. OUTPUT PARAMETERS FOR THE TRAJECTORY PROGRAM OF MODEL B

Parameter Names	Definition
TTLAT1	Latitude of endpoint of trajectory 1
TTLON1	Longitude of endpoint of trajectory 1
UBAR1	Mean wind speed along trajectory 1
SPREA1	Dispersion parameter along trajectory 1
ALPHA1	Angle α along trajectory 1, defined in Fig. 8
BETA1	Angle β along trajectory 1, defined in Fig. 8
T1	Distance t along trajectory 1, defined in Fig. 8
R21	Distance d along trajectory 1, defined in Fig. 8
IJK1	Direction indicator along trajectory 1
TTLAT2	Latitude of endpoint of trajectory 2
TTLON2	Longitude of endpoint of trajectory 2
UBAR2	Mean wind speed along trajectory 2
SPREA2	Dispersion parameter along trajectory 2
ALPHA2	Angle α along trajectory 2
BETA2	Angle β along trajectory 2
T2	Distance t along trajectory 2
R22	Distance d along trajectory 2
IJK2	Direction indicator along trajectory 2
TTLAT3	Latitude of endpoint of trajectory 3
TTLON3	Longitude of endpoint of trajectory 3
UBAR3	Mean wind speed along trajectory 3
SPREA3	Dispersion parameter along trajectory 3
ALPHA3	Angle α along trajectory 3
BETA3	Angle β along trajectory 3
T3	Distance t along trajectory 3
R23	Distance d along trajectory 3
IJK3	Direction indicator along trajectory 3
TTLAT4	Latitude of endpoint of trajectory 4
TTLON4	Longitude of endpoint of trajectory 4
UBAR4	Mean wind speed along trajectory 4
SPREA4	Dispersion parameter along trajectory 4
ALPHA4	Angle α along trajectory 4
BETA4	Angle β along trajectory 4
T4	Distance t along trajectory 4
R24	Distance d along trajectory 4
IJK4	Direction indicator along trajectory 4

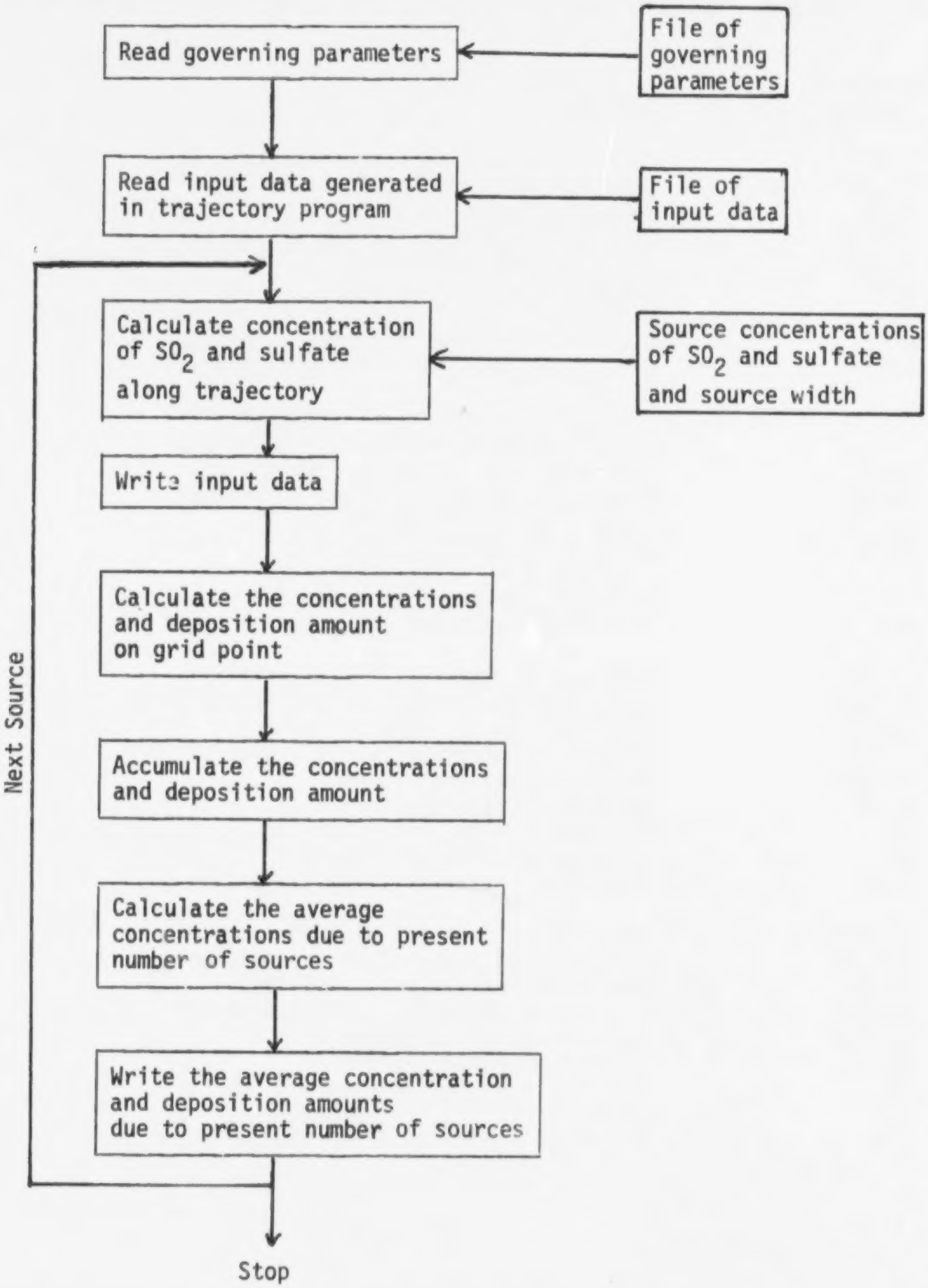
Read governing parameters
File of governing parameters
Read input data generated in trajectory program
File of input data
Calculate concentration of SO2 and sulfate along trajectory
Source concentrations of SO2 and sulfate and source width
Write input data
Calculate the concentrations and deposition amount on grid point
Accumulate the concentrations and deposition amount
Calculate the average concentrations due to present number of sources
Write the average concentration and deposition amounts due to present number of sources
Next Source
Stop

Figure 27. Flow chart of concentration calculations by Model A.

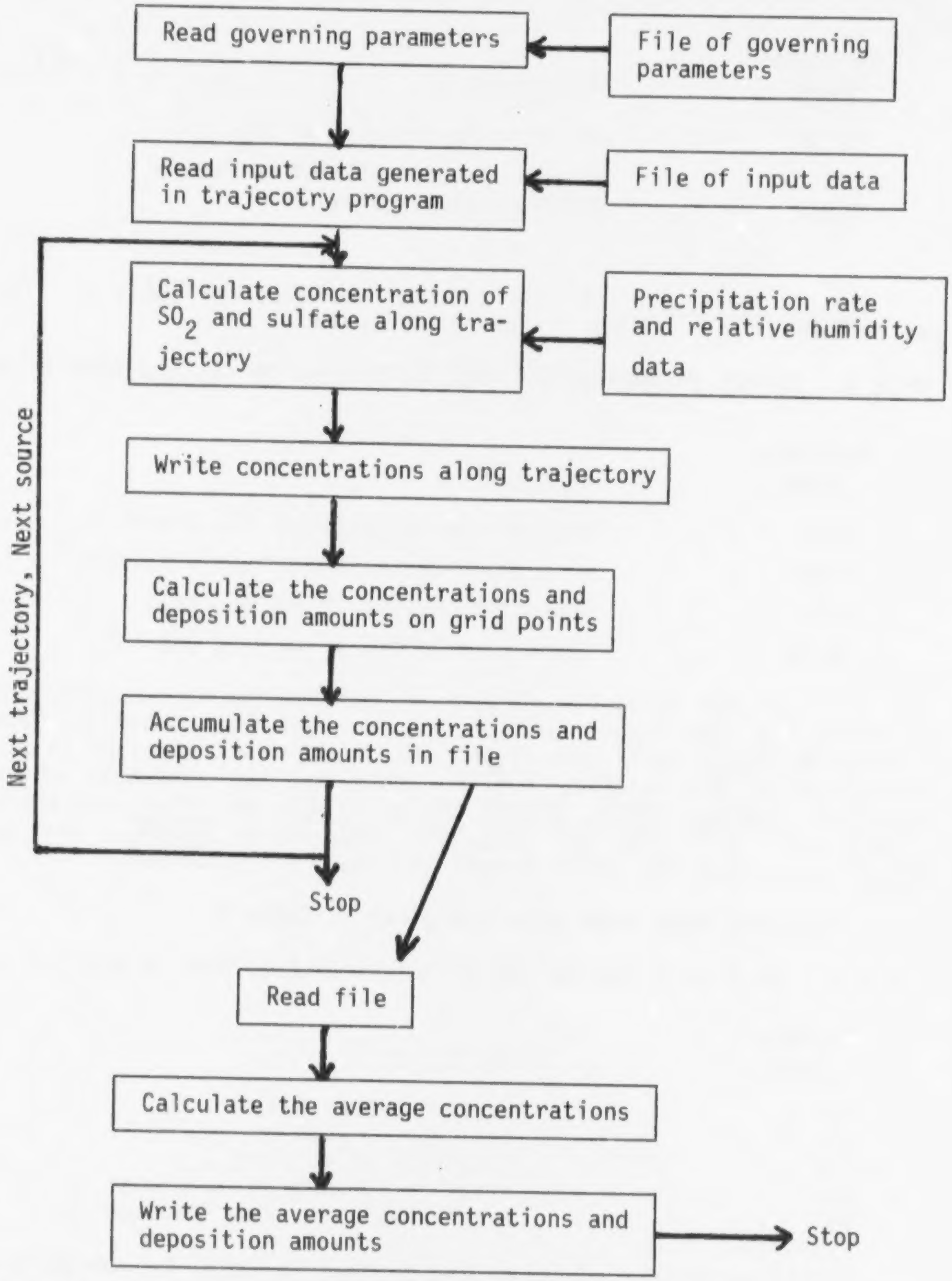
Read governing parameters
File of governing parameters
Read input data generated in trajecotry program
File of input data
Calculate concentration of SO_2 and sulfate along trajectory
Precipitation rate and relative humidity data
Write concentrations along trajectory
Calculate the concentrations and deposition amounts on grid points
Accumulate the concentrations and deposition amounts in file
Next trajectory, Next source
Stop
Read file
Calculate the average concentrations
Write the average concentrations and deposition amounts
Stop

Figure 28. Flow chart of concentration calculations by Model B.

TABLE 5. INPUT DATA FOR THE CONCENTRATION CALCULATIONS OF MODEL A

Parameter Name	Definition
ORCON	Source concentration of SO_2
SORCON	Source concentration of sulfate
WIORO	Width of source area

Output parameters of this program are shown in Table 6. These output parameters are written for every grid point.

TABLE 6. OUTPUT PARAMETERS OF THE CONCENTRATION CALCULATIONS OF MODEL A

Parameter Name	Definition
XXJ	Average concentration of SO_2 ($\mu g/m^3$)
SXXJ	Average concentration of sulfate ($\mu g/m^3$)
DXXJ	Deposition amount of SO_2 (Kg/Km^2)
DSXXJ	Deposition amount of sulfate (Kg/Km^2)

The role of the subroutine DETCON is to redefine the concentration value according to the number of trajectories and the number of loops. The subroutine PRECIP calls upon TRIANG and its attendant routines to interpolate precipitation and relative humidity data for the midpoints of trajectory segments. CONHUL, TMESH, TMESHI, SORTRI, PVEC, and STEST, and the functions TRINTR and LTEST are the attendant routines to TRIANG. The subroutine BADGET calculates the sulfur budget in the area of interest.

Input data read from cards are given in Table 7.

TABLE 7. INPUT DATA FOR THE CONCENTRATION CALCULATIONS OF MODEL B

Parameter Name	Definition
IST	Station number
LAT	Latitude of station
LON	Longitude of station
RH	Relative humidity at stations
PS	Precipitation rate at stations

Output parameters of Model B are shown in Table 8. In addition to the various parameters at grid points, the concentrations along trajectories are given as output.

TABLE 8. OUTPUT PARAMETERS OF THE CONCENTRATION CALCULATION PROGRAM OF MODEL B

Parameter Name	Definition
I	Number of trajectory
TSLAT	Latitude of trajectory endpoint
TSLON	Longitude of trajectory endpoint
CONC	Concentration of SO_2 along trajectory
SCONC	Concentration of sulfate along trajectory
M	Subscript for the loop of day
K	Subscript for the loop of trajectory per day
J	Subscript for the loop of trajectory segment
XXJ	Average surface concentration of SO_2 ($\mu g/m^3$)
XXJ2	Average concentration of SO_2 above the nighttime mixing height ($\mu g/m^3$)
SXXJ	Average surface concentration of sulfate ($\mu g/m^3$)
SXXJ2	Average concentration of sulfate above the nighttime mixing height ($\mu g/m^3$)
DXXJ	Deposition amount of SO_2 (Kg/Km^2)
DSXXJ	Deposition amount of sulfate (Kg/Km^2)
PXXJ	Precipitation deposition amount of SO_2 (Kg/Km^2)
PSXXJ	Precipitation deposition amount of sulfate (Kg/Km^2)

FORTRAN programs of Model A and Model B are given in Appendix A and B, respectively.

CHAPTER 6

APPLICATIONS OF THE MODEL

6.1 INTRODUCTION

In this chapter we describe the results of model applications. From Model B we calculated the geographical distributions of average concentrations of SO_2 and of sulfate over the region between 35°N and 45°N and between 75°W and 95°W, which encompasses the Ohio River basin. Two applications were made. In application (1), 10-day averaged concentrations and deposition amounts of SO_2 and sulfate were calculated. In application (2), 24-hour averaged concentrations and deposition amounts over the region were calculated. The computed concentrations at the surface level were compared with the concentrations observed at stations located in the region.

6.2 APPLICATION (1)

6.2.1 Input Data

In this application we calculated 10-day averaged concentrations for the period from May 1 to May 10, 1974. Averaged precipitation scavenging velocities and average relative humidities based on climatological data were used to calculate removal rates of SO_2 and sulfate and transformation rates of SO_2 to sulfate. Figures 29 and 30 were obtained by interpolating the data which were observed at sixty weather stations in the eastern United States. The data were used for the period between May and October, 1974.

Sixty point sources of SO_2 whose emission rate is more than 10^5 ton/year were taken into consideration. The geographical locations and the emission rates are shown in Fig. 31 (Clark, 1978). Other input data used for the calculations, in addition to precipitation scavenging velocity, relative humidity and emission rate, are as follows:

Daytime mixing height	1600 m
Nighttime stable layer height	250 m
Dry deposition velocity of SO_2	
daytime	2 cm/sec
nighttime	1 cm/sec

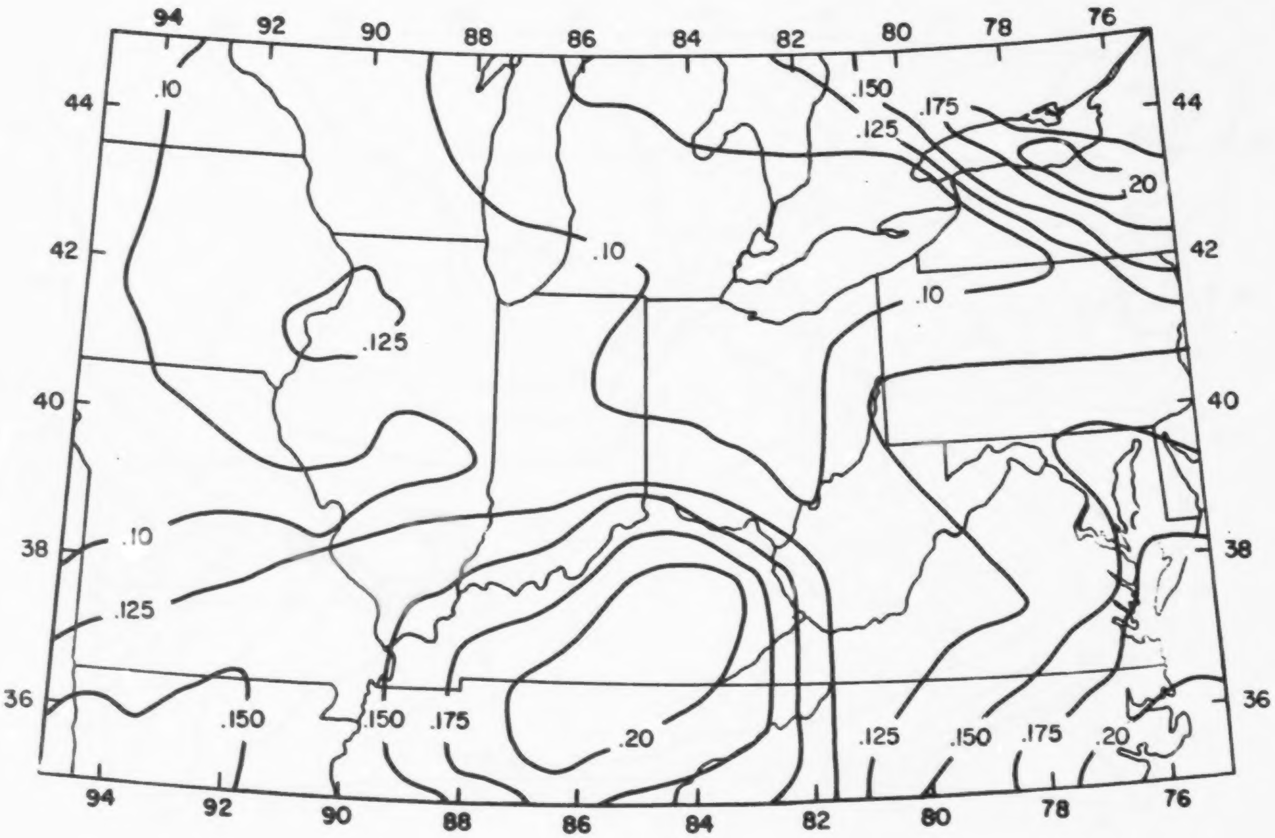
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Figure 29. Distribution of removal velocity (cm/sec) due to precipitation for warm season (May-October), 1974.

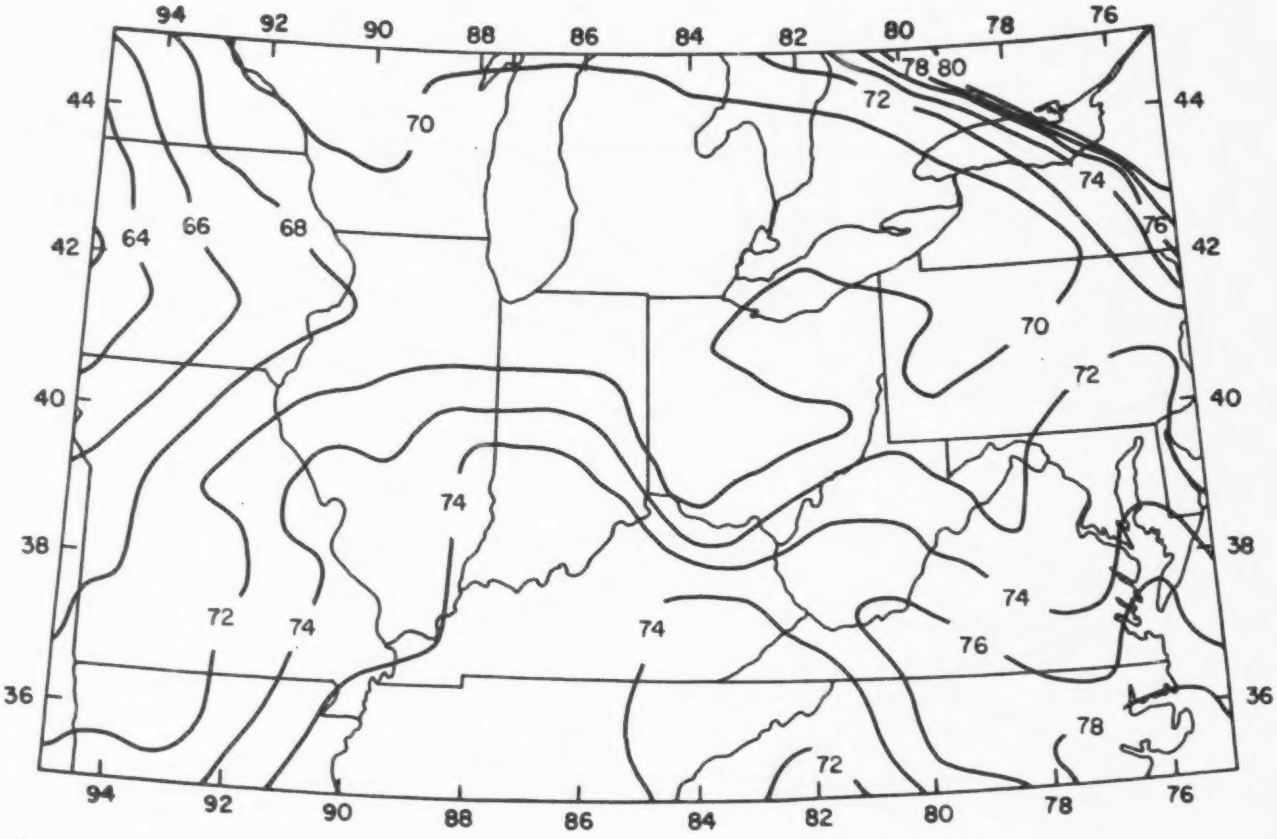
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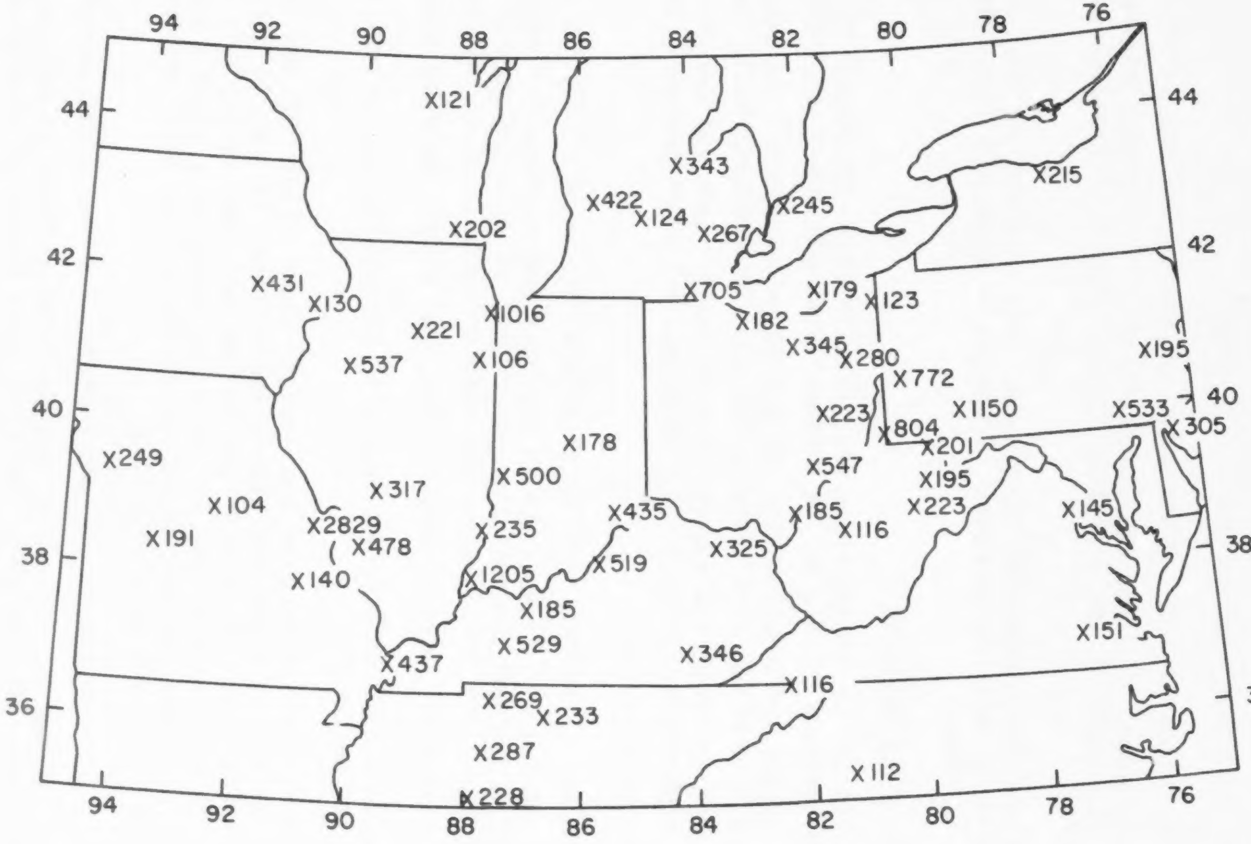
Figure 30. Distribution of average ground level relative humidity (percent) for warm season (May-October), 1974.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X215
X202
X431
X130
X221
X1016
X705
X179
X123
X182
X345
X280
X195
X537
X106
X772
X223
X1150
X533
X305
X804
X201
X178
X547
X195
X249
X500
X317
X104
X435
X185
X223
X145
X2829
X235
X116
X191
X478
X325
X140
X1205
X519
X185
X151
X529
X346
X437
X116
X269
X233
X287
X112
X228

Figure 31. Locations and emission intensities (x 10^3 ton/year) of major SO_2 point source.

Dry deposition velocity of sulfate	
daytime	0.2 cm/sec
nighttime	0.1 cm/sec
The ratio (κ/χ) for SO_2	5×10^4
The ratio (κ/χ) for sulfate	5×10^4

(κ/χ) are the ratios of the concentration of SO_2 or sulfate in rainwater to the concentrations of those pollutants in air. The heights of the daytime mixing layer and of the nighttime stable layer were based on data by Holzworth (1972).

Calculations were conducted using wind data provided by the Air Resources Laboratory, NOAA at Maryland. Trajecotries were initiated from each source every 12 hours.

6.2.2 Results and Discussion

The results of our computations are shown in Figs. 32 through 37. The average concentrations of SO_2 at the surface level and above the nighttime stable layer height are shown in Figs. 32 and 33, respectively. As expected, high concentrations of SO_2 were found in the area surrounding strong sources. The eastern part of Ohio, the western part of Pennsylvania and West Virginia were under a high concentration of SO_2, where several point sources with high emission rates were located.

Distributions of sulfate were more uniform than those of SO_2, as can be seen in Figs. 34 and 35. This is due to the fact that sulfate is formed with time, and that a maximum concentration of sulfate is attained several hours after SO_2 emission from the source. The computed amounts of sulfate concentrations were several factors greater than the values observed normally.

The concentrations vary sensitively with changes in the removal terms, as discussed in Chapter 7.

The distribution patterns at the surface level (Figs. 32 and 34) and at the level above the nighttime stable layer (Figs. 33 and 35) were only slightly different. This is probably due to the fact that during this 10-day period the wind shear with height was not large enough to produce a significant difference between the concentrations at the surface level and those at the level above the nighttime stable layer.

The deposition amounts of SO_2 and sulfate, for the 10-day period, are shown in Figs. 36 and 37. It can be seen that the patterns of contour lines of SO_2 as well as of sulfate were similar to the patterns of concentrations of the respective pollutants at the surface level. Since the deposition amount is calculated as the product of surface level concentration times

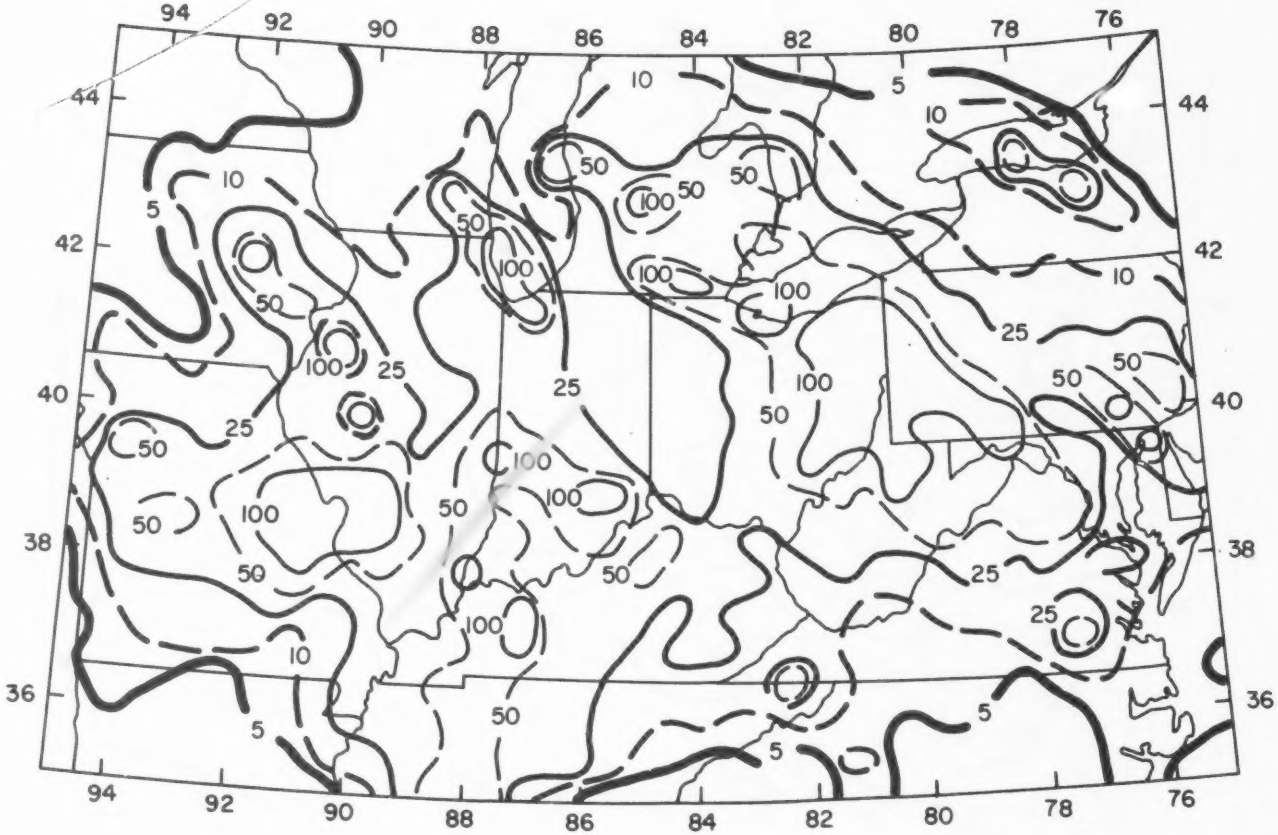
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Figure 32. Distribution of average SO_2 concentrations ($\mu g/m^3$) at the surface for the period of May 1 through 10, 1974.

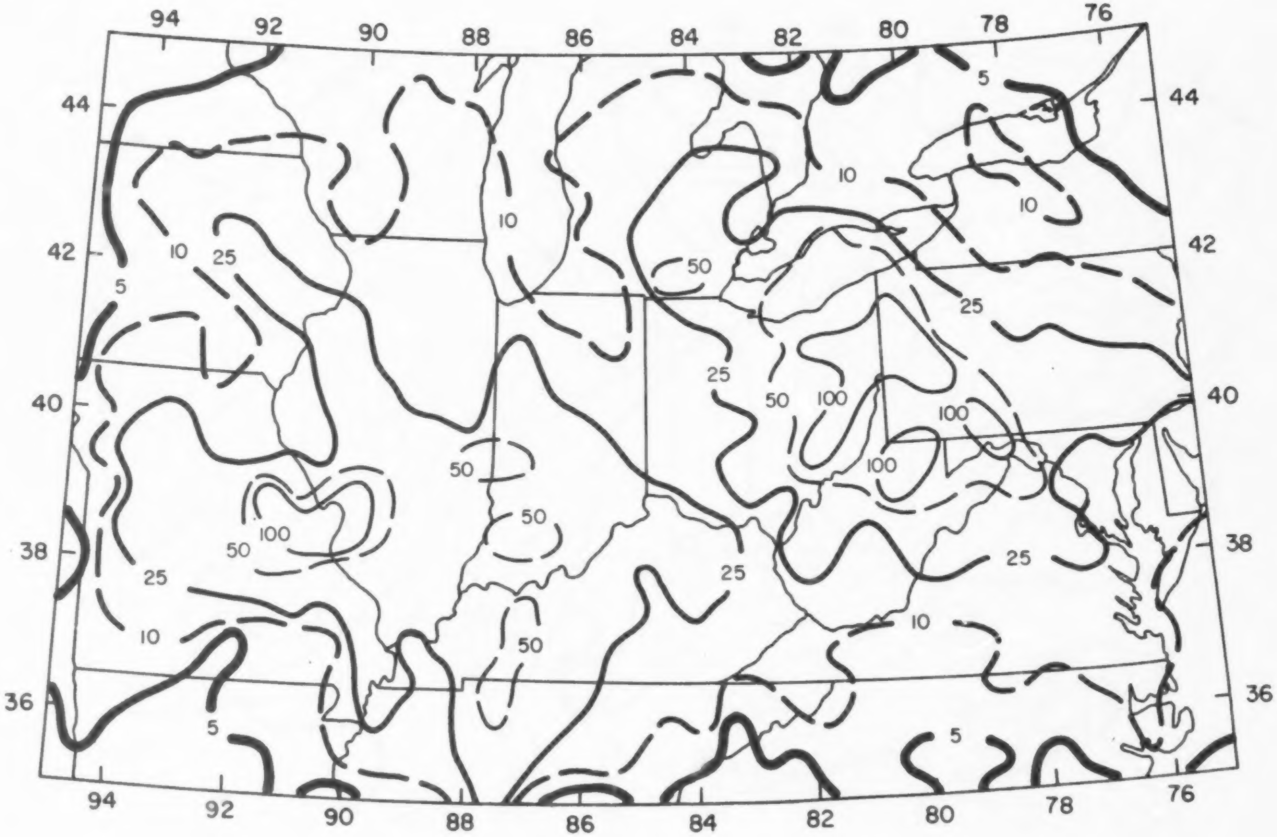
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Figure 33. Distribution of average SO_2 concentrations ($\mu g/m^3$) above the nighttime mixing height for the period of May 1 through 10, 1974.

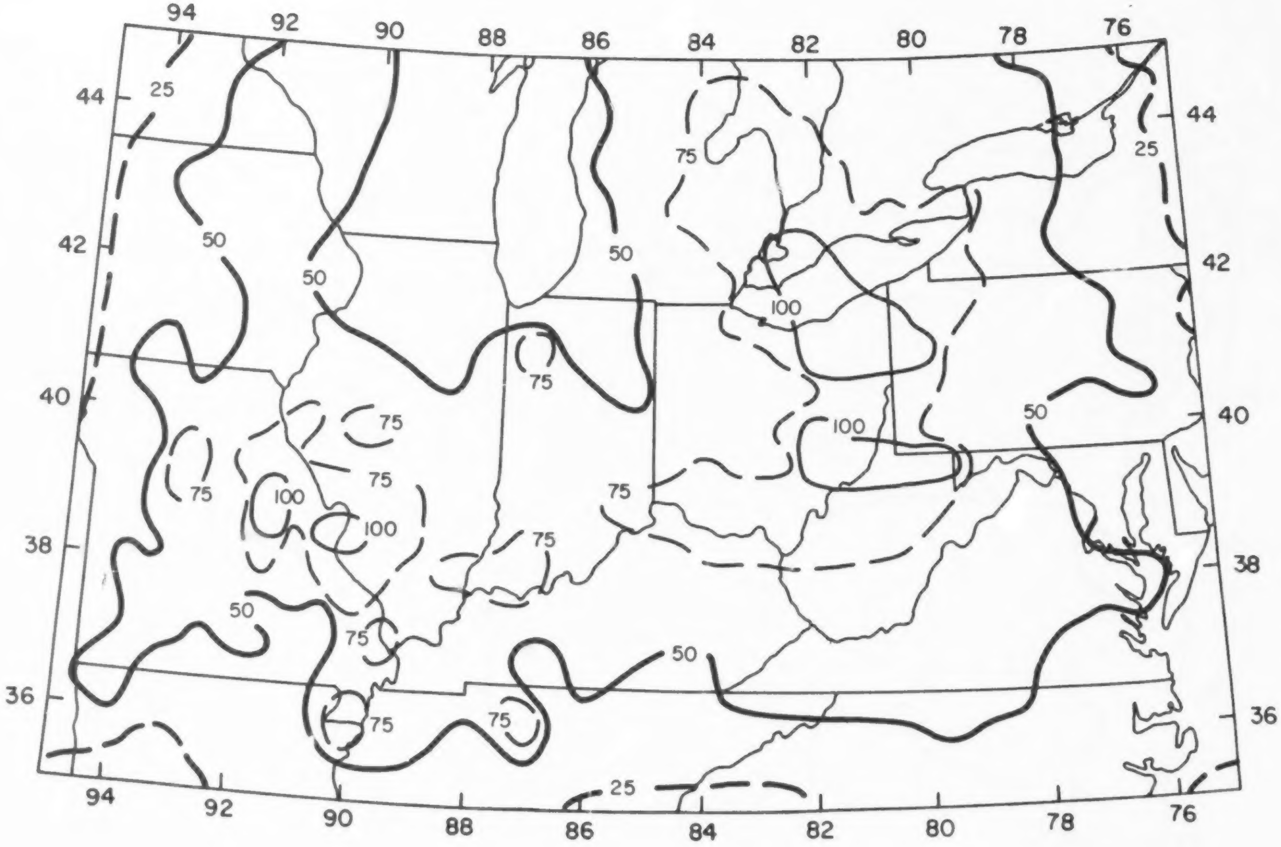
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Figure 34. Distribution of average sulfate concentrations ($\mu g/m^3$) at the surface for the period of May 1 through 10, 1974.

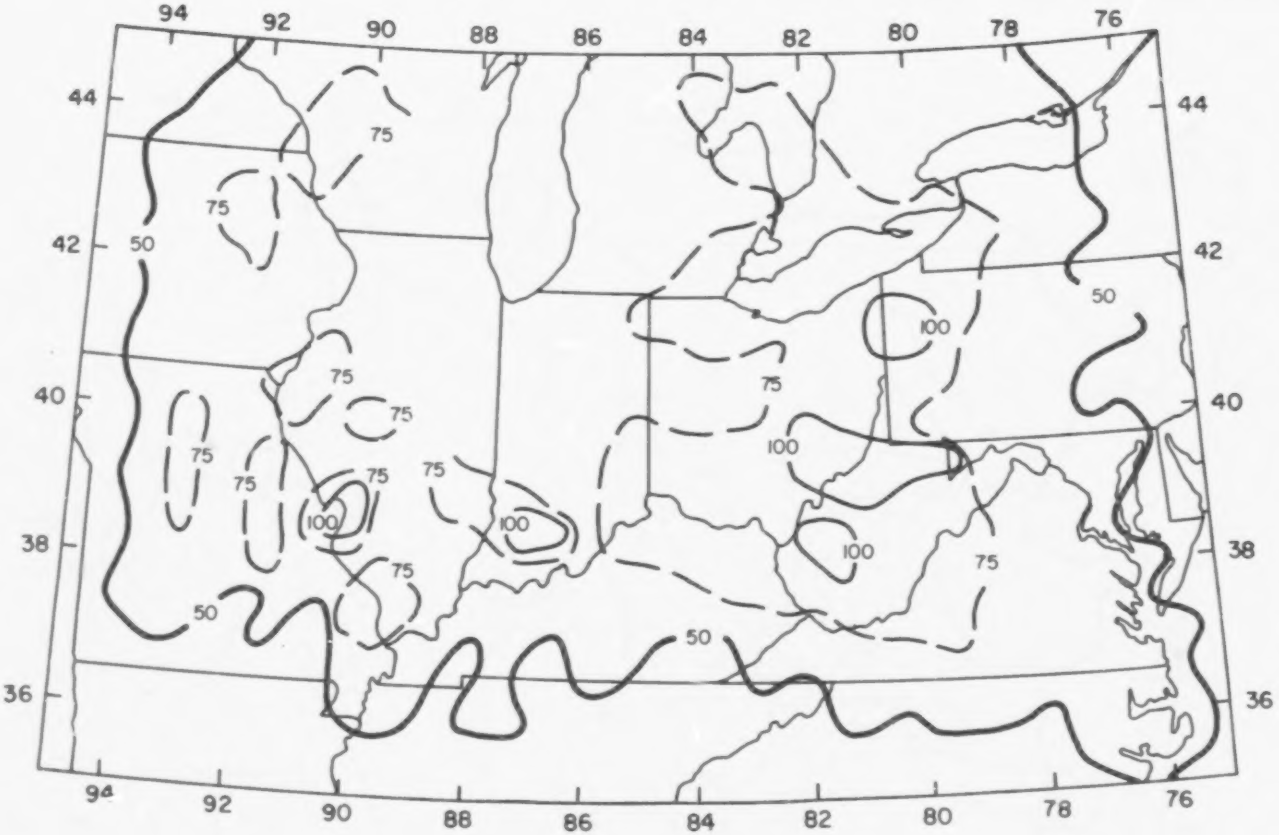

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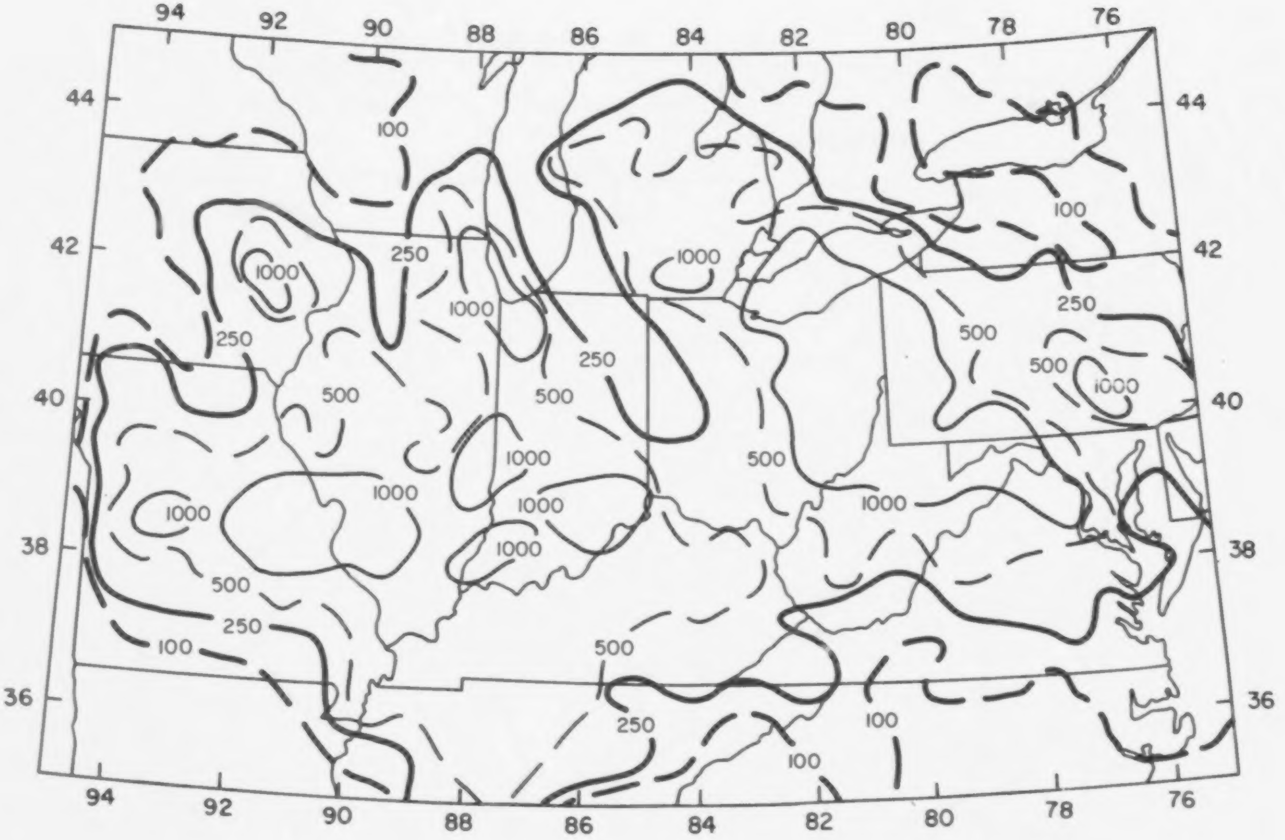
Figure 35. Distribution of average sulfate concentrations (μg/m^3 above the nighttime mixing height for the period of May 1 through 10, 1974.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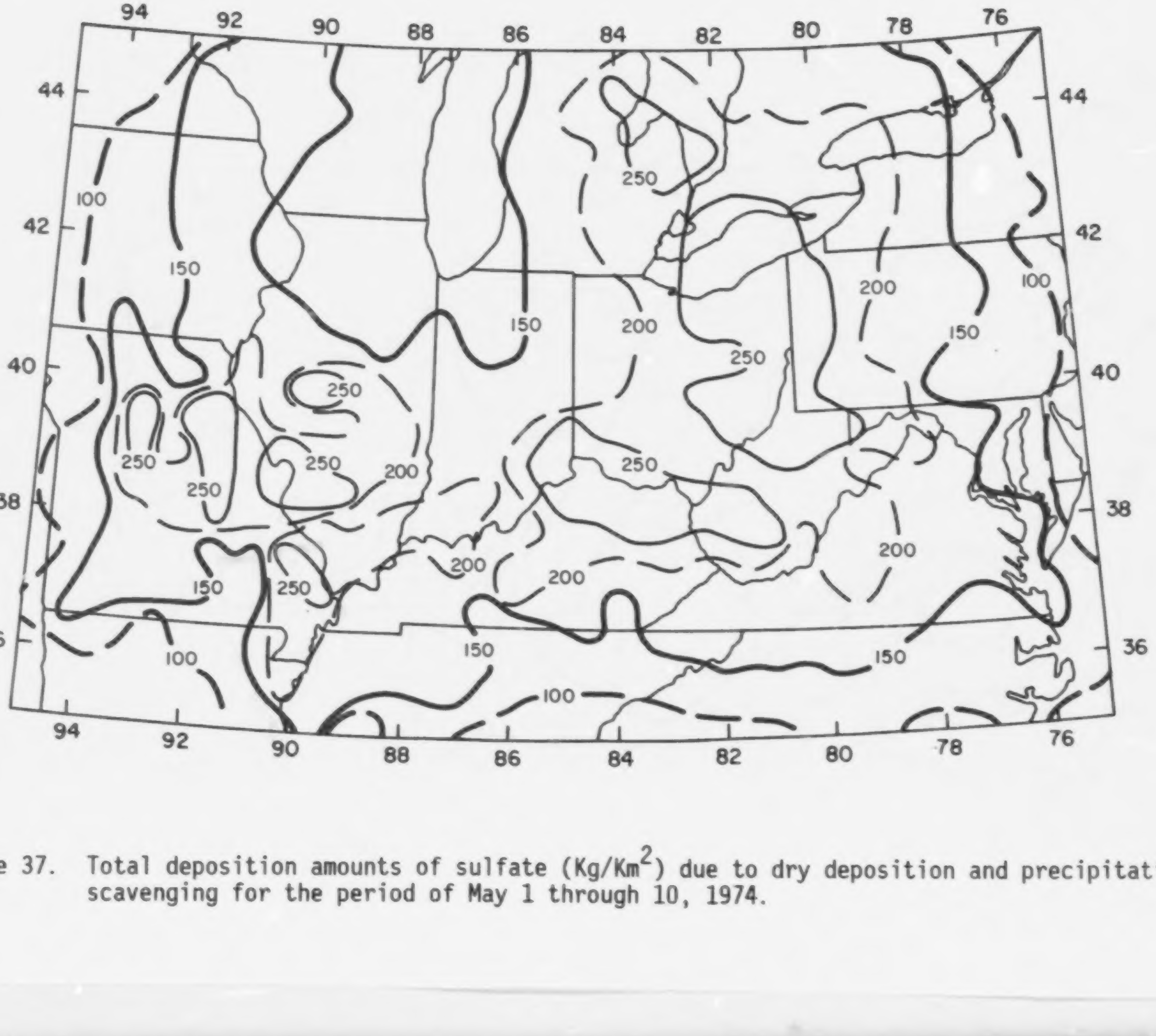
100
250
500
1000

Figure 36. Total deposition amounts (Kg/Km^2) of SO_2 due to dry deposition and precipitation scavenging for the period of May 1 through 10, 1974.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44
42
40
38
36
100
150
200
250

Figure 37. Total deposition amounts of sulfate (Kg/Km^2) due to dry deposition and precipitation scavenging for the period of May 1 through 10, 1974.

deposition velocity, including dry and wet deposition, the similarity mentioned above could be expected.

6.3 APPLICATION (2)

In this application we calculated the distributions of 24-hour average concentrations and deposition amounts of SO_2 and sulfate over the region between 35°N and 45°N and between 75°W and 95°W. The concentrations of SO_2 and of sulfate were measured most extensively over the region on May 11, 1974. In order to verify our model we calculated the 24-hour average concentrations for the same day.

6.3.1 Input Data

From application (1), we learned that the concentration values of sulfate calculated over the region were several factors greater than the values observed normally. In order to obtain more realistic and dependable results, we used the following assumptions for the removal terms:

Dry deposition velocity of SO_2

Daytime	2 cm/sec
Nighttime	2 cm/sec

Dry deposition velocity of sulfate

Daytime	0.4 cm/sec
Nighttime	0.4 cm/sec.

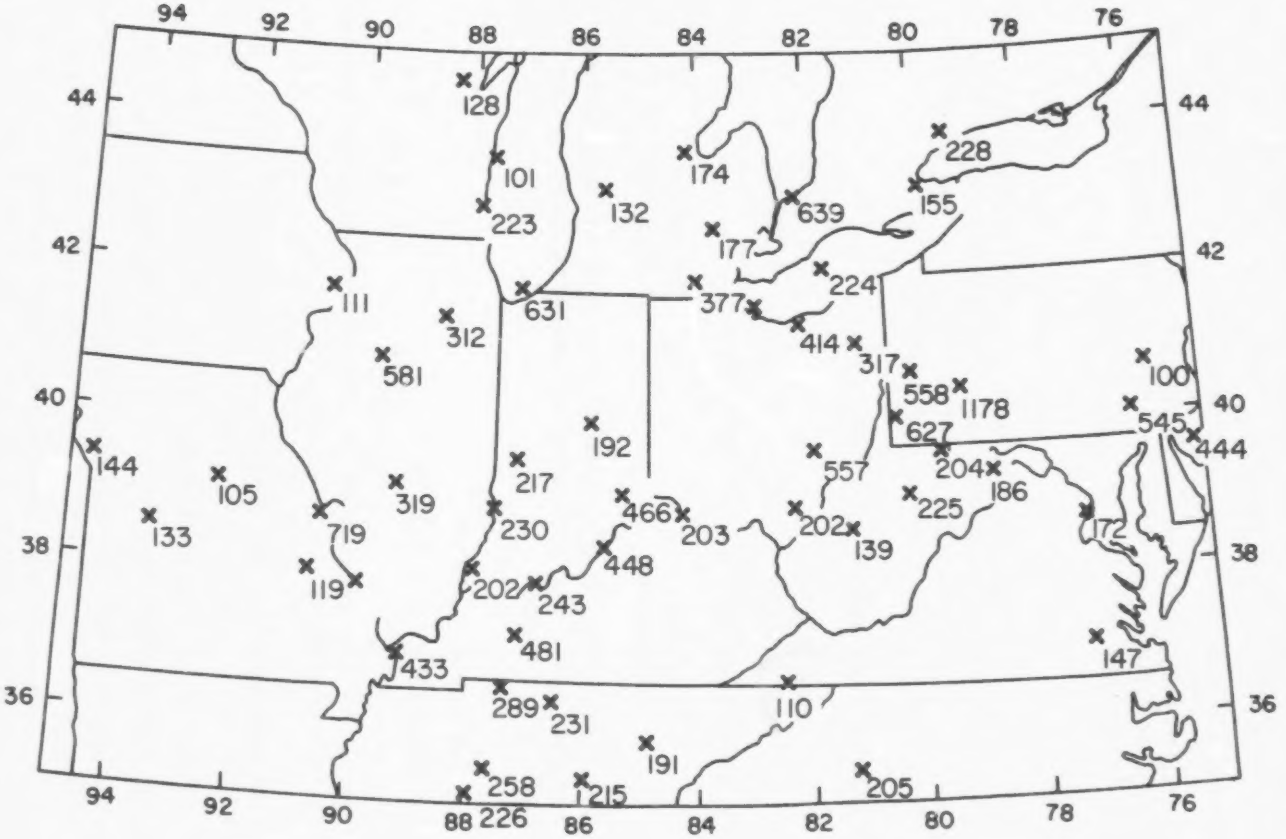
Because of the difficulty in obtaining hourly data of relative humidity over the region for the past, the following values were used for the transformation rate of SO_2 to sulfate:

Daytime $K = 0.1\ hr^{-1}$

Nighttime $K = 0.01\ hr^{-1}$

Such a difference in the magnitudes of transformation rates between daytime and nighttime is reported by Husar et al. (1977).

Another change made in the present calculations is in the value of the dimensionless ratio $(\kappa/\chi)_v$ for SO_2 and sulfate. Here κ is the pollutant content of rainwater and χ is the concentration in air. In the previous application, it was assumed that (κ/χ) for both SO_2 and sulfate is 5×10^4. In the present application, we assume that (κ/χ) is 5×10^5. Eventually the assumption of equal values of this ratio for both, SO_2 and sulfate, will have to yield as more observational evidence becomes available. In Fig. 38 the locations and the emission rates of major SO_2 sources used for the calculations are shown. As was the case in application (1), the SO_2 sources whose


94
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177
228
155
224
377
414
317
111
312
631
581
558
1178
627
100
545
444
144
105
133
719
119
319
217
230
192
466
203
557
202
139
204
186
225
172
448
202
243
481
433
289
231
110
191
205
258
226
215
147

Figure 38. Locations and intensities of SO_2 emission sources (x 10^3 ton/year).

emission rates are more than 10^5 ton/year are taken into consideration. The emission of SO_2 from these sources contains about 90 percent of the total emission over the area.

Clark's (1978) original emission rate estimate of SO_2 was revised after application (1) was carried out. For the present purpose, gridded emission maps of SO_2 for the United States and Canada east of the Rocky Mountains supplied by EPA (Clark, 1979) were used.

The data of precipitation rate and precipitation probability for 81 stations located in the region were used to calculate the deposition amounts. The following heights were used:

Daytime mixing height	1600 m
Nighttime stable layer	250 m

6.3.2 Method of Calculation

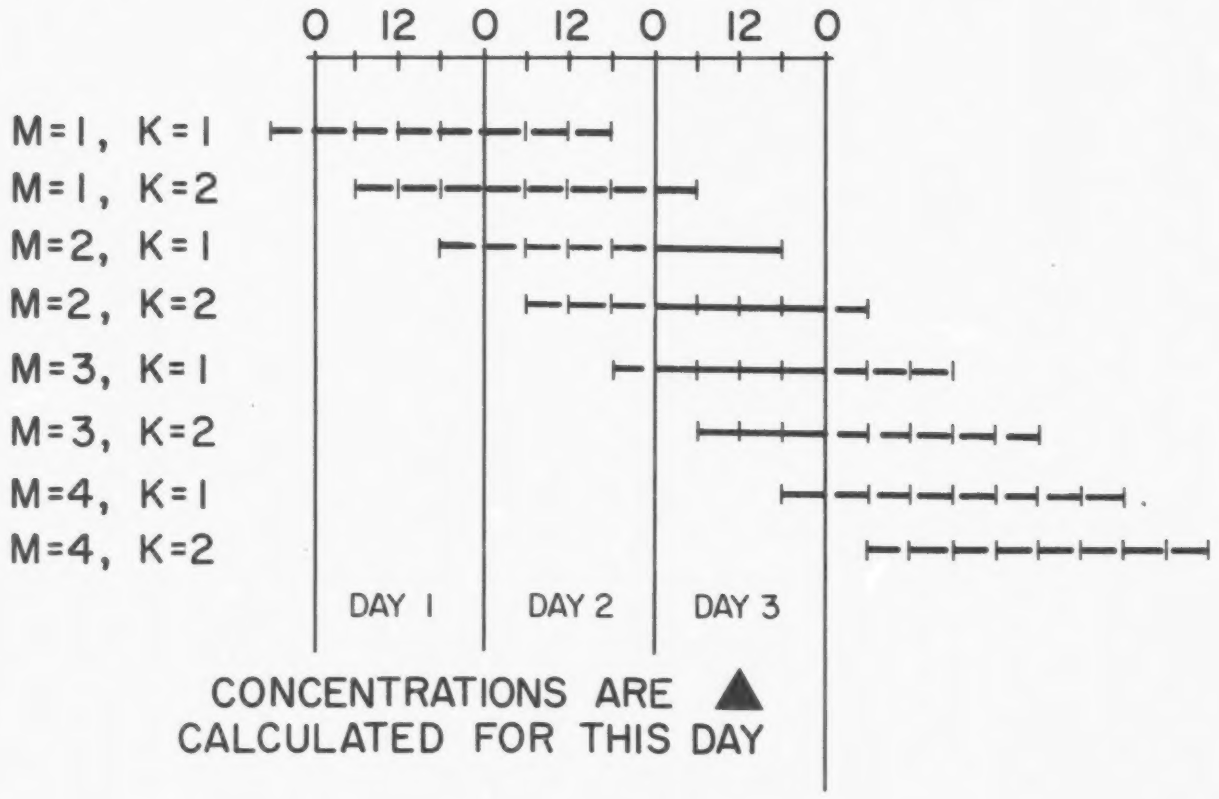
Trajectories from each source area were calculated every 12 hours, starting at 6 and 18 CST, and each trajectory was pursued for 48 hours. Therefore, in order to calculate 24-hour average concentrations, we must take into consideration the contributions of trajectories which started up to 2 days earlier. In Fig. 39, the scheme for calculating 24-hour concentrations is shown. Trajectory segments drawn in solid lines were used to calculate the 24-hour average concentrations. For this calculation, 1-degree grid spacing was used to save computing time.

6.3.3 Results and Discussion

The distributions of 24-hour average concentrations of SO_2 at the surface and above the nighttime stable layer are shown in Figs. 40 and 41. It can be seen that high concentrations of SO_2 were calculated over the area surrounding the sources.

Figures 42 and 43 contain the distributions of sulfate concentration at the surface level and at the level above the nighttime stable layer. Both figures show the very widespread area covering several states under high concentration of sulfate on this day. Clear air covered the western part of this region (Iowa and Missouri).

The distributions of deposition amounts of SO_2 and sulfate due to both, dry deposition and precipitation, are shown in Figs. 44 and 45. The distributions of deposition amounts of SO_2 and sulfate due to precipitation only are shown in Figs. 46 and 47. On May 11, 1974, some of the eastern states did not receive precipitation, thus no deposition due to precipitation was recounted there.


0
12
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12
0
M=1, K=1
M=1, K=2
M=2, K=1
M=2, K=2
M=3, K=1
M=3, K=2
M=4, K=1
M=4, K=2
DAY 1
DAY 2
DAY 3
CONCENTRATIONS ARE ▲
CALCULATED FOR THIS DAY

Figure 39. Scheme of calculating 24-hour average concentrations.

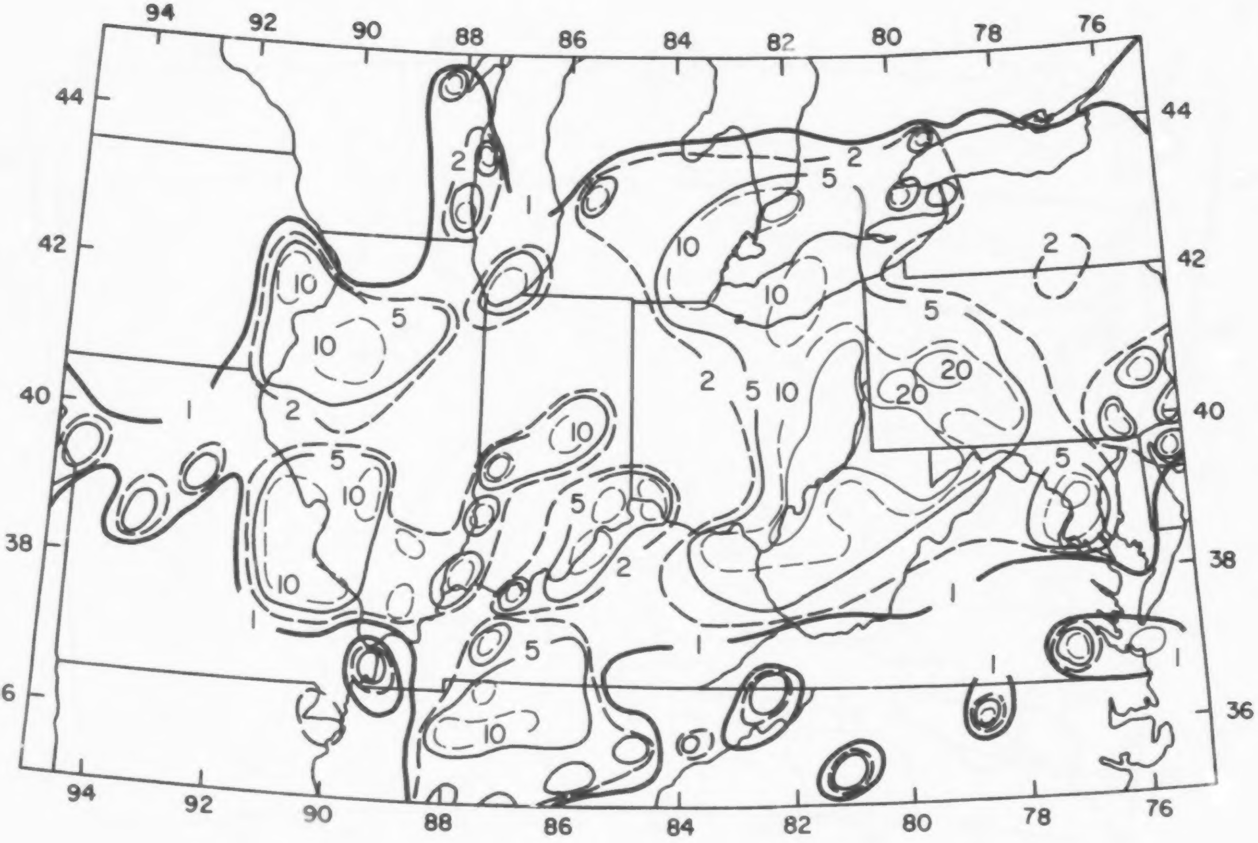
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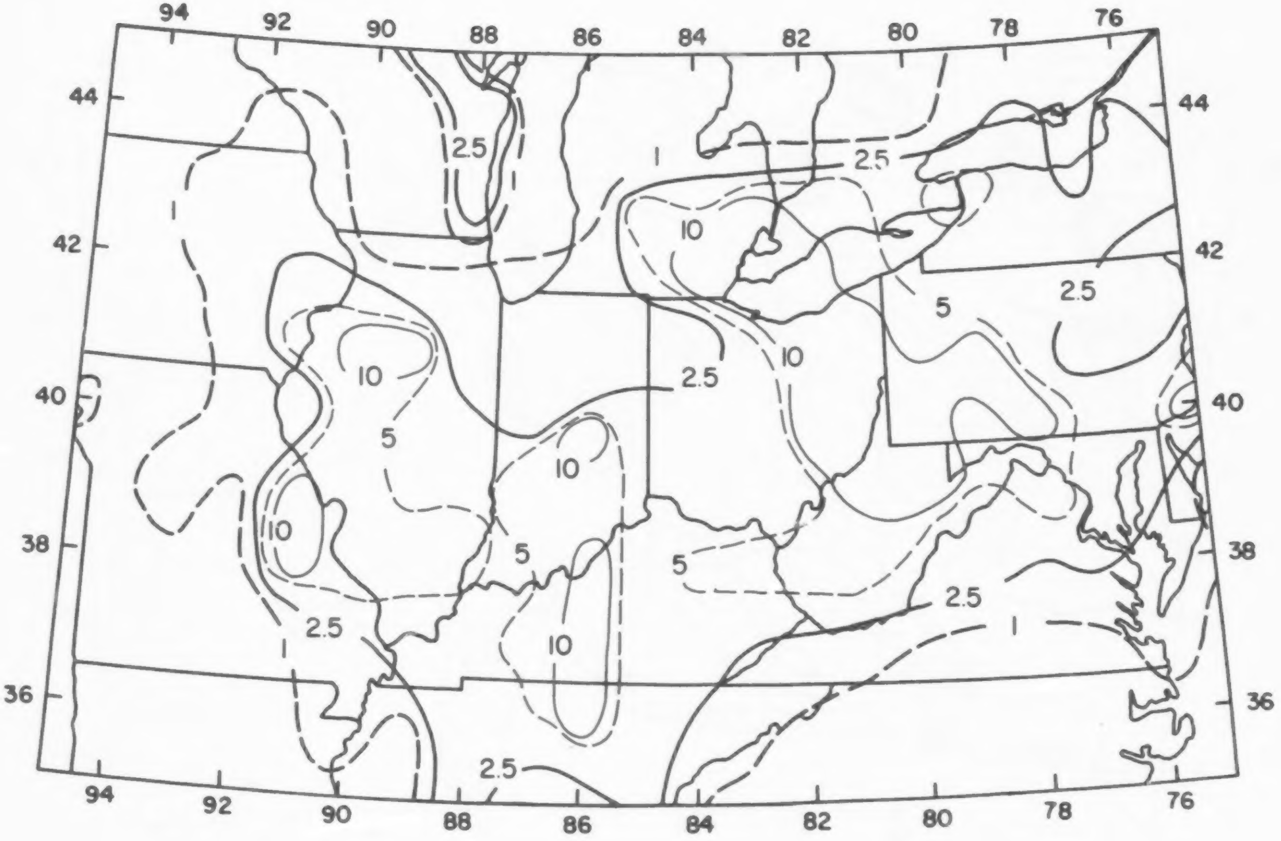
Figure 40. Distribution of SO_2 concentrations ($\mu g/m^3$) at the surface level on May 11, 1974.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10
5
2.5
10
2.5
10
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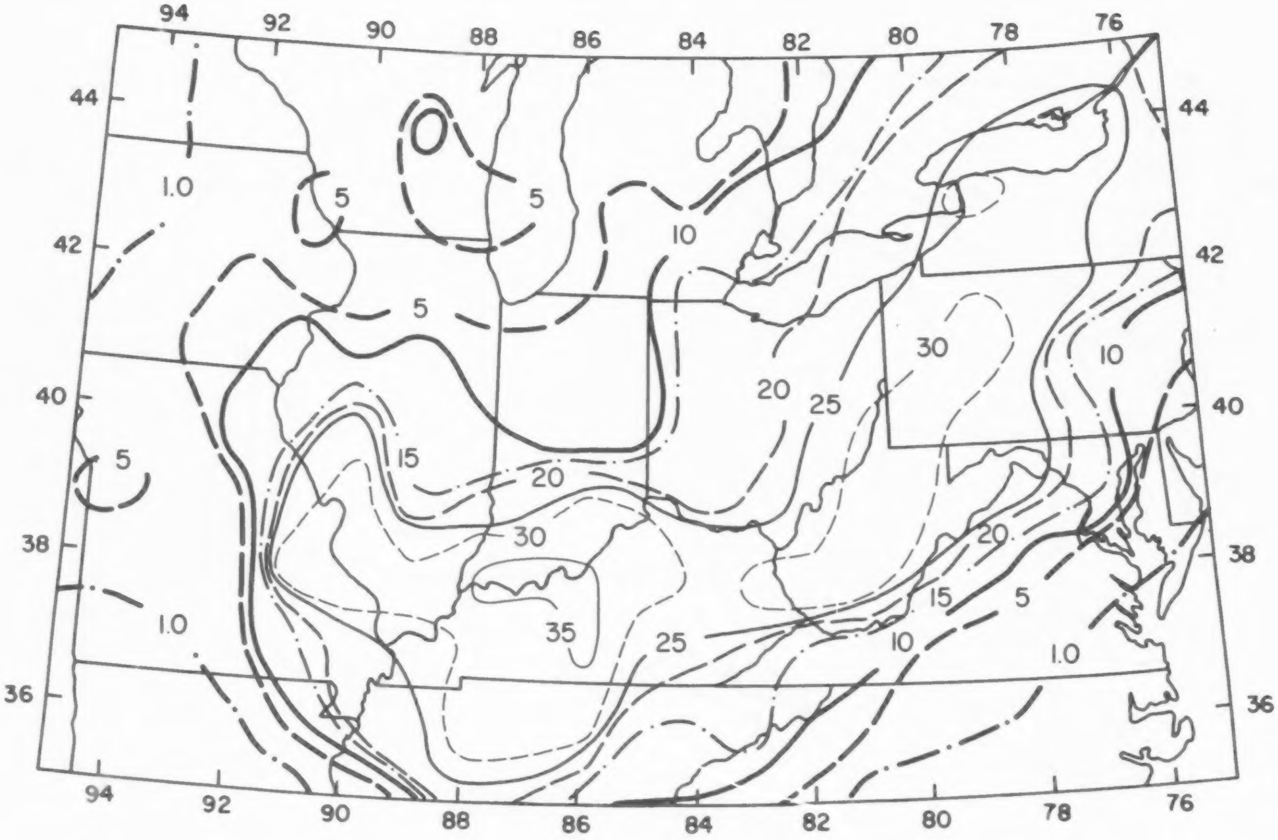
1

Figure 41. Distribution of SO_2 concentrations ($\mu g/m^3$) above the nighttime stable layer.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10
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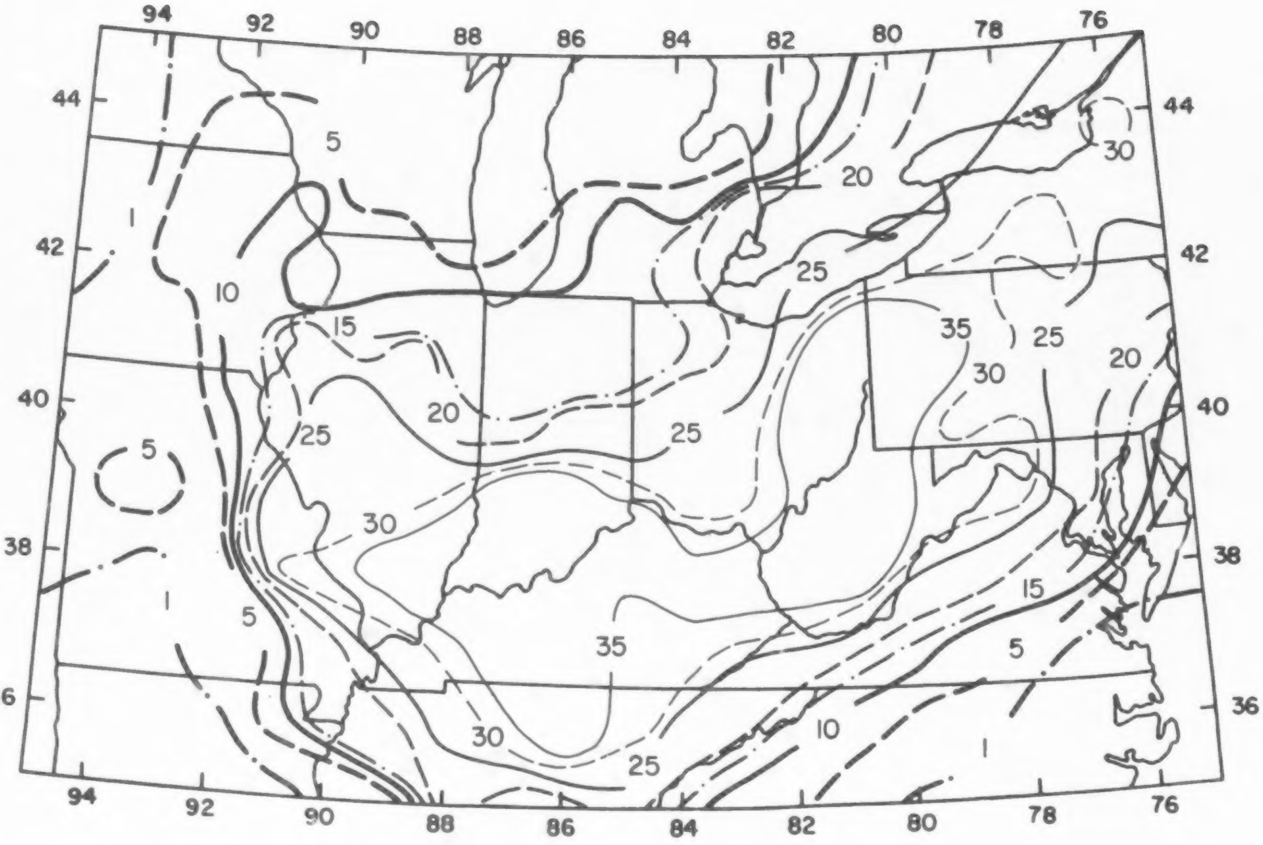
Figure 42. Distribution of sulfate concentrations ($\mu g/m^3$) at the surface level on May 11, 1974.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35

Figure 43. Distribution of sulfate concentrations ($\mu g/m^3$) above the nighttime stable layer, on May 11, 1974.

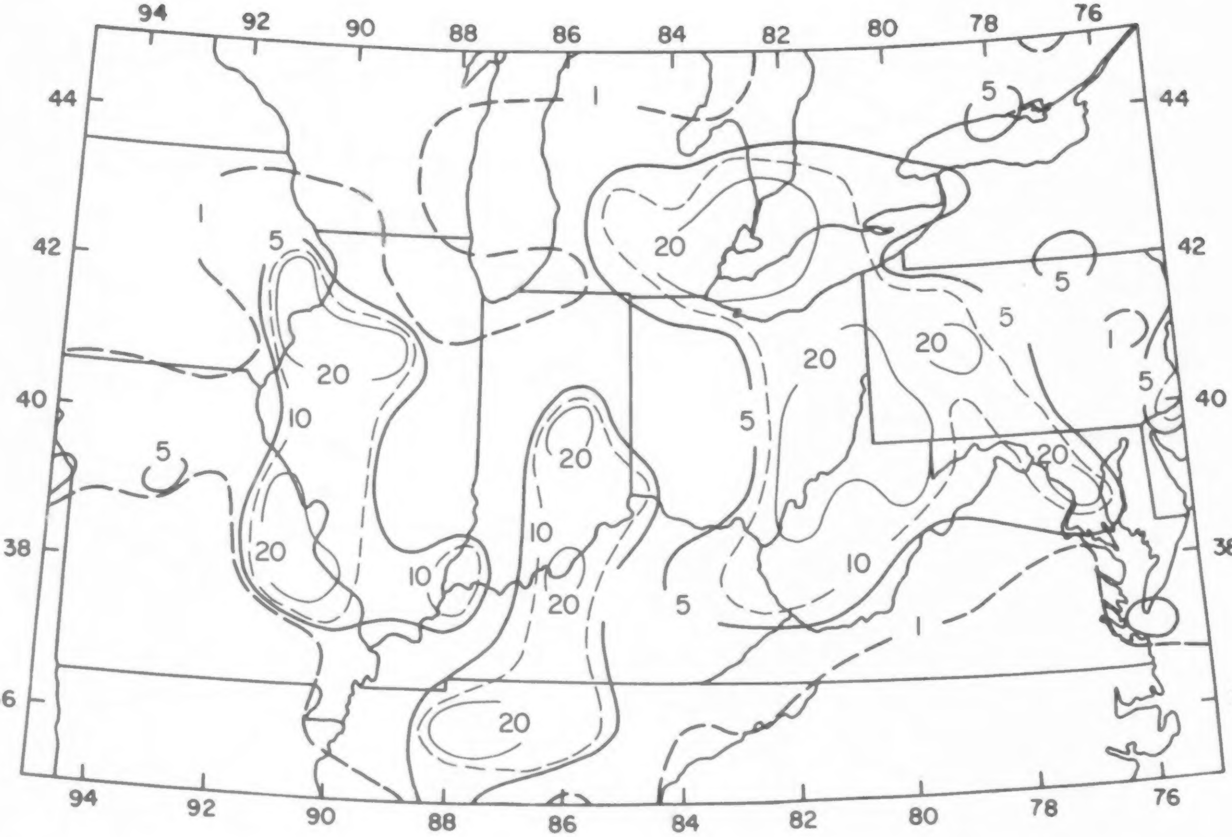
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Figure 44. Distribution of SO_2 deposition amounts (Kg/Km^2) due to dry deposition plus precipitation on May 11, 1974.

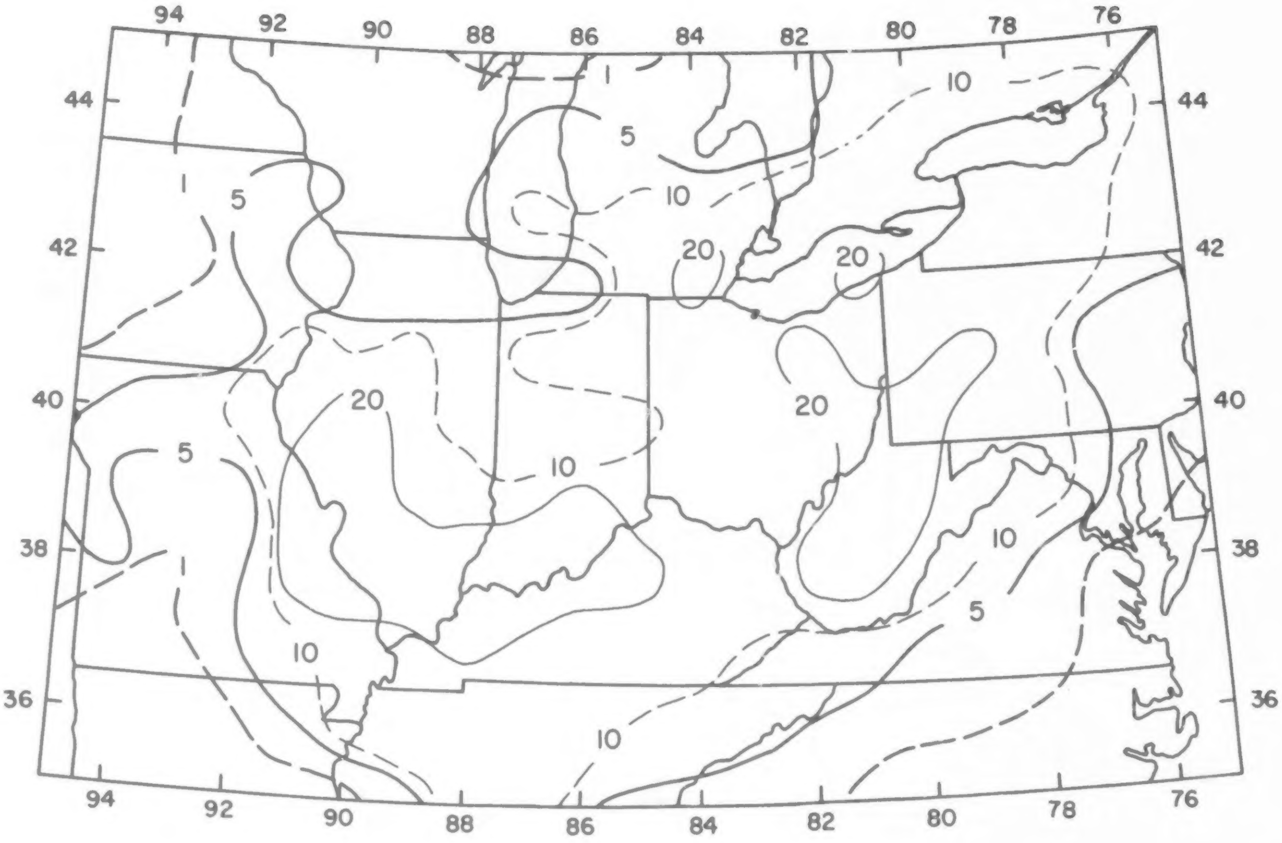
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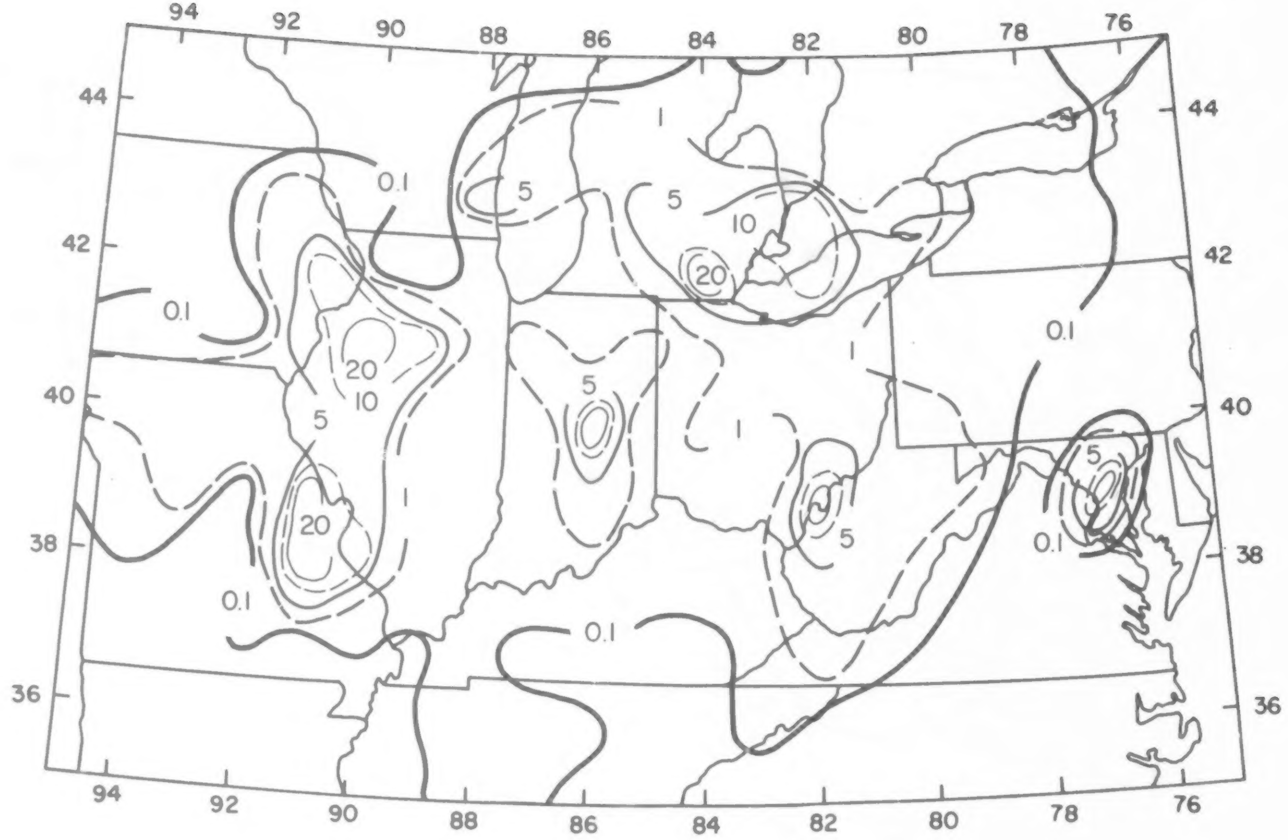
Figure 45. Distribution of sulfate deposition amounts (Kg/Km^2) due to dry deposition plus precipitation on May 11, 1974.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0.1
20
10
5
20
0.1
5
0.1
5
0.1
0.1
5
94
92
90
88
86
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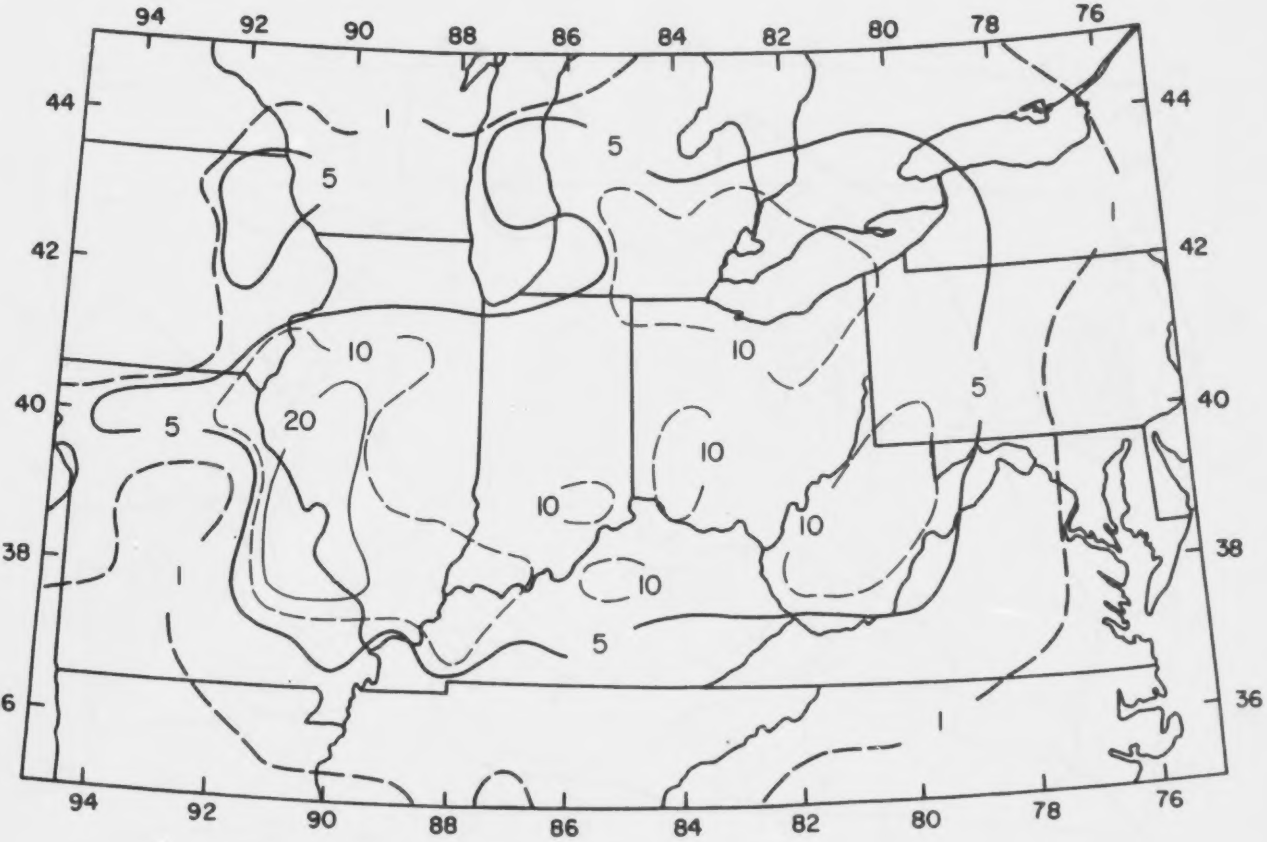
36

Figure 46. Distribution of SO_2 deposition amounts (Kg/Km^2) due to precipitation only on May 11, 1974.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10
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5
1
1

Figure 47. Distribution of sulfate deposition amounts (Kg/Km^2) due to precipitation only on May 11, 1974.

The sulfur budget over the region was calculated as follows:

Sulfur emission	24,546 tons
Removal by wet deposition	
as SO_2	4,293 tons
as sulfate	3,005 tons
	7,298 tons
Removal by dry deposition	
as SO_2	10,176 tons
as sulfate	2,771 tons
	12,947 tons
Total deposition of sulfur	20,246 tons
Amount exported from the boundaries of the region	4,300 tons

According to these calculations, about 30 percent of sulfur are removed by precipitation, about 53 percent are removed by dry deposition and only 17 percent are exported from the boundary of the region. Of course, these estimates are based on the removal parameters used.

In order to verify the performance of the model, the concentrations of SO_2 and sulfate calculated for the surface level were compared with concentrations observed at stations located in the region. Observed data supplied by EPA were used.

Numerous stations observed SO_2 concentrations on May 11, 1974. In order to avoid data points containing local effects, we used only those data taken at stations classified as "rural", "remote", and "suburban-residential" (EPA, 1974). Data taken at 73 stations defined as above, were compared with the calculated concentrations of SO_2. On the other hand, the number of stations which observed the sulfate concentrations is limited. Sulfate data taken at 41 stations, regardless of their classifications, were compared.

The observed concentrations of SO_2 are plotted in Fig. 48 against the calculated ones. Similar plots for sulfate are shown in Fig. 49. Notice that the scales are logarithmic in both figures. A few points in both diagrams are overlapping.

The correlation coefficients between the mean deviation of the observed concentrations and mean deviation of the calculated concentrations were calculated as follows:

for SO_2 concentrations, $r = 0.635$, $r_c = 0.302$

and for sulfate concentrations, $r = 0.487$, $r_c = 0.393$.

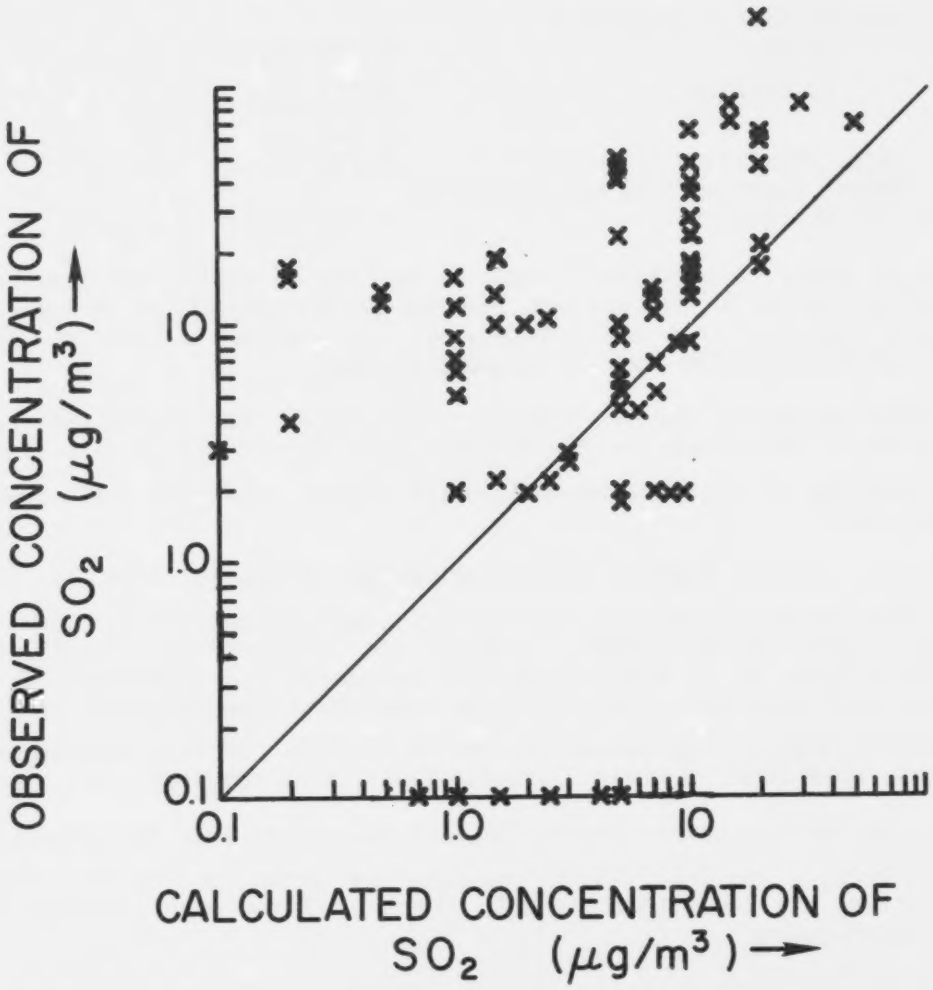


Figure 48. Relationship between calculated and observed SO_2 concentration.

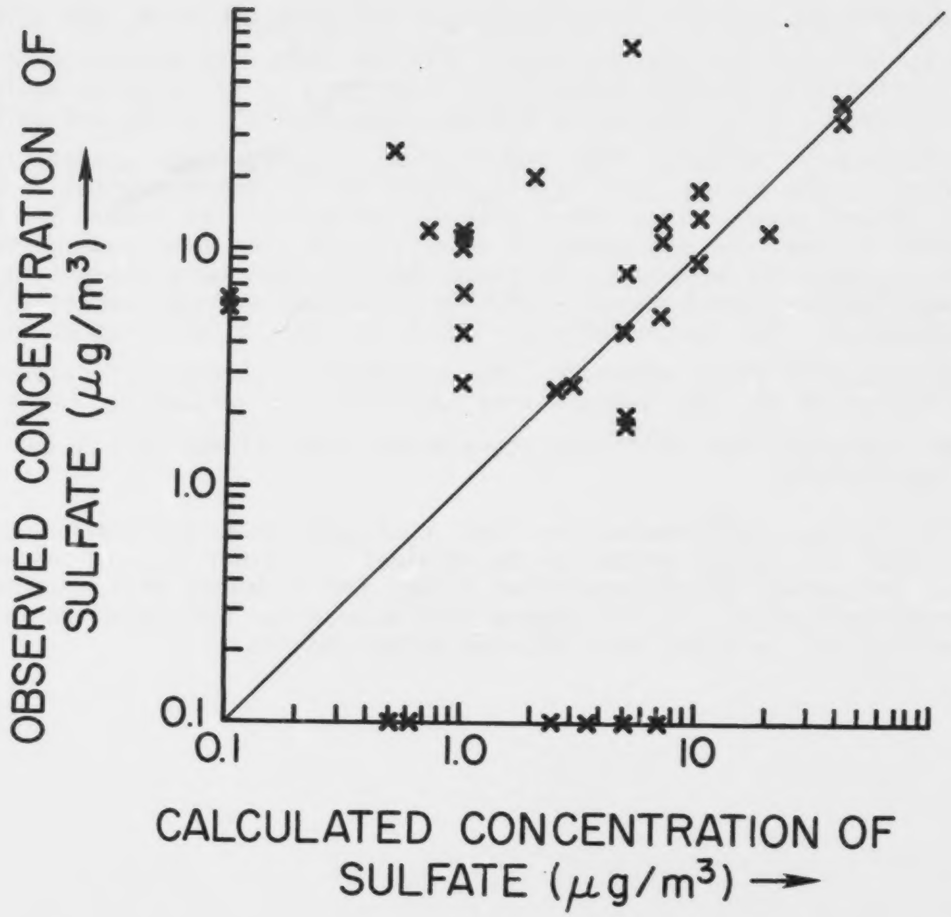


Figure 49. Relationship between calculated and observed sulfate concentration.

Here, r is the correlation coefficient, r_c is the critical value for correlation coefficients with 99.9% confidence levels. Since r is larger than r_c in both SO_2 and sulfate, we can conclude that the distribution patterns of calculated concentrations of SO_2 and sulfate are statistically related to those of observed concentrations with the correlation coefficients r = 0.635 and 0.487, respectively.

6.4 SUMMARY

The model was applied to calculate the distributions of SO_2 and sulfate concentrations over the region between 35°N and 45°N, and between 75°W and 95°W. In the first example, using climatological data of relative humidity and precipitation rate, the 10-day average concentrations of SO_2 and sulfate were calculated. Although the distribution patterns seem qualitatively reasonable, it was noticed that the magnitudes of sulfate concentration were several factors greater than those observed normally. The reason for this discrepancy is that the magnitudes of removal terms used were inappropriate. For this reason, the magnitudes of these removal terms were changed in the second application, where the distribution of 24-hour average concentrations were calculated. The concentrations of both SO_2 and sulfate thus obtained were compared with those observed. The distribution patterns of calculated concentrations of SO_2 and sulfate were statistically related to those of observed concentrations with the correlation coefficients r = 0.635 and 0.487, respectively.

With further refinements, we feel confident that correlation coefficients with even larger values can be obtained. In order to save computing time, we calculated the concentration values for 1 degree grid spacing in the second application. If 0.5 degree grid spacing had been used, as in the first application, we might have obtained better results.

CHAPTER 7

REGIONAL RESIDENCE TIMES OF SO_2 AND SULFATE OVER THE EASTERN UNITED STATES

7.1 INTRODUCTION

A parameter which adequately characterizes the fate of pollutants over long time- and space-scales is the "residence time" or "turnover time" in the atmosphere. The residence time of a pollutant can be defined as the time required to decrease the burden of that pollutant in the atmosphere over a certain region to a value which is 1/e of the original value, assuming that no further input of the pollutant into the atmosphere from below or across the lateral boundaries of the region occurs. The turnover time is the time equal to the total mass of a pollutant in the atmosphere over a certain region divided by the removal flux of the pollutant.

We calculated the residence time of SO_2 over the eastern U.S. (Henmi et al., 1977 and 1978). However, there were shortcomings in those earlier studies: (i) the transformation rate of SO_2 to sulfate was assumed to be constant and (ii) the residence time of sulfate was not considered.

In the present study, the observational data on transformation rates were scrutinized and an empirical formula for the transformation rate as a function of relative humidity was deduced. The residence time of sulfate was defined mathematically.

Calculations were made of the regional residence times of SO_2 and sulfate over the region of the United States east of 105°W longitude where major industrial activities are located. The year was divided into the cold season (January - April, and November and December) and the warm season (May - October), and the regional residence times for each of these two seasons were calculated.

7.2 DATA USED

7.2.1 Mean Mixing-Layer Height, $\bar{H}$, and Precipitation Data

Mean mixing-layer height and precipitation data were analyzed in a previous study (Henmi et al., 1977 and 1978). The same data were used here.

7.2.2 Relative Humidity Data

Since the transformation rate of SO_2 to sulfate is derived as a function of relative humidity, data on relative humidity are necessary as input. The monthly average relative humidities of the year of 1974 were obtained from the Climatological Data, National Summary (U.S. Department of Commerce, 1974), and the seasonal average values for 61 stations located in the study area were used for the computation of transformation data.

Figures 50 and 51 show the seasonal average relative humidities over the eastern U.S. for the cold season and the warm season, respectively.

7.3 APPROACH

7.3.1 Residence Times of SO_2 and Sulfate

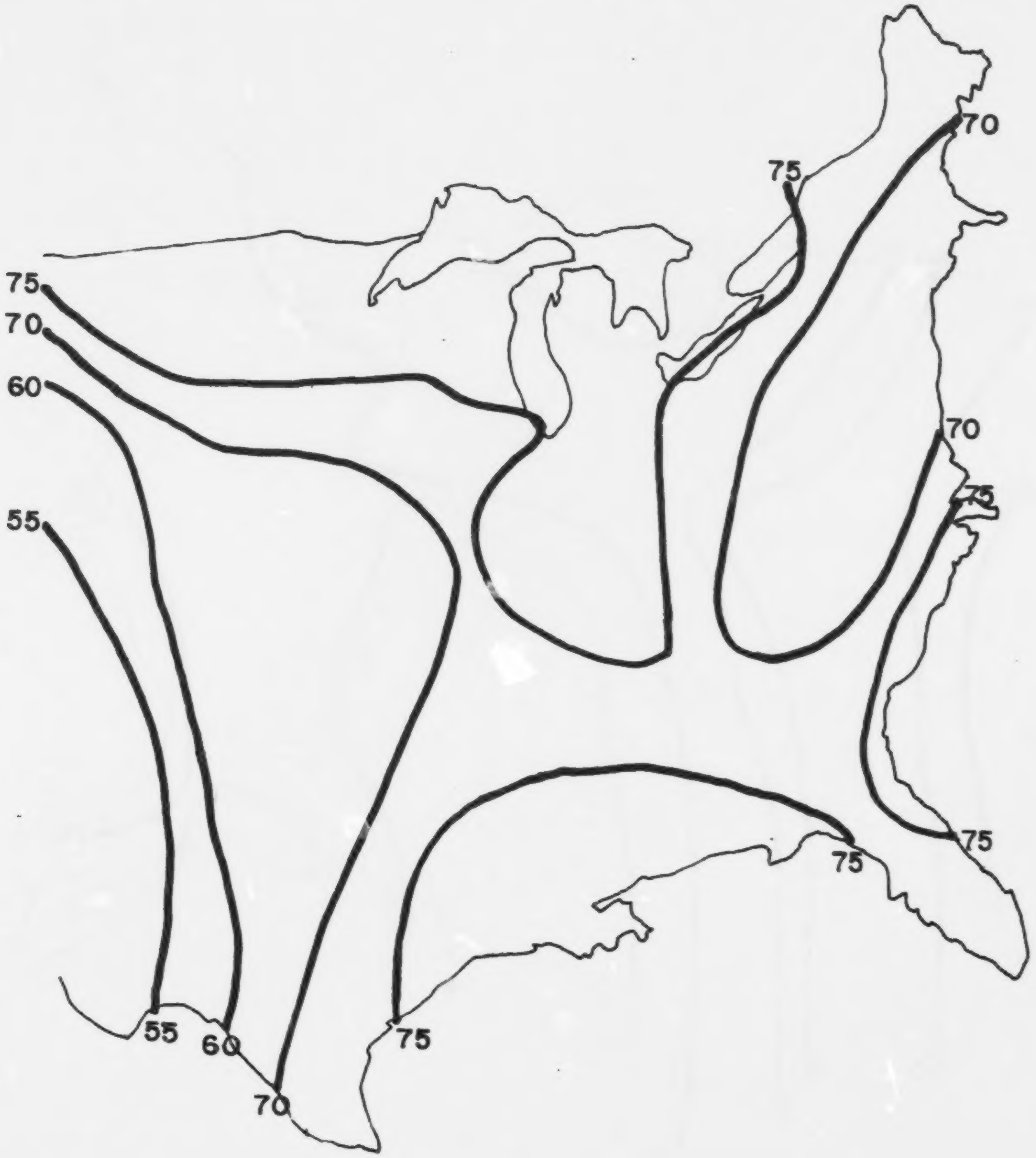
In order to calculate the residence times of SO_2 and sulfate, we assume that they are distributed uniformly vertically through the mixing layer, that no significant net transports of the pollutants occur across the boundaries of the region, that the pollutants are removed from the layer by dry deposition and precipitation scavenging, and that SO_2 is transformed into sulfate by a first-order reaction. Under these assumptions, we can write

$$\frac{dC_1}{dt} = -(\lambda_{d_1} + k_{p_1} + K)C_1 \qquad (21)$$

$$\frac{dC_2}{dt} = -(\lambda_{d_2} + k_{p_2})C_2 + \frac{3}{2} KC_1 \qquad (22)$$

C_1 and C_2 are the concentrations of SO_2 and of sulfate, λ_{d_1} and λ_{d_2} are the depletion rates due to dry deposition, k_{p_1} and k_{p_2} are the depletion rates due to precipitation. Subscripts 1 and 2 stand for SO_2 and sulfate. The transformation rate from SO_2 to sulfate is represented by K. The ratio $\frac{3}{2}$ is the ratio of molecular weights of sulfate ($SO_4^=$) to sulfur dioxide (SO_2). The solutions to these equations are given by

$$C_1 = C_{10} \exp[-(\lambda_{d_1} + k_{p_1} + K)t] \qquad (23)$$


70
75
75
70
60
70
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75
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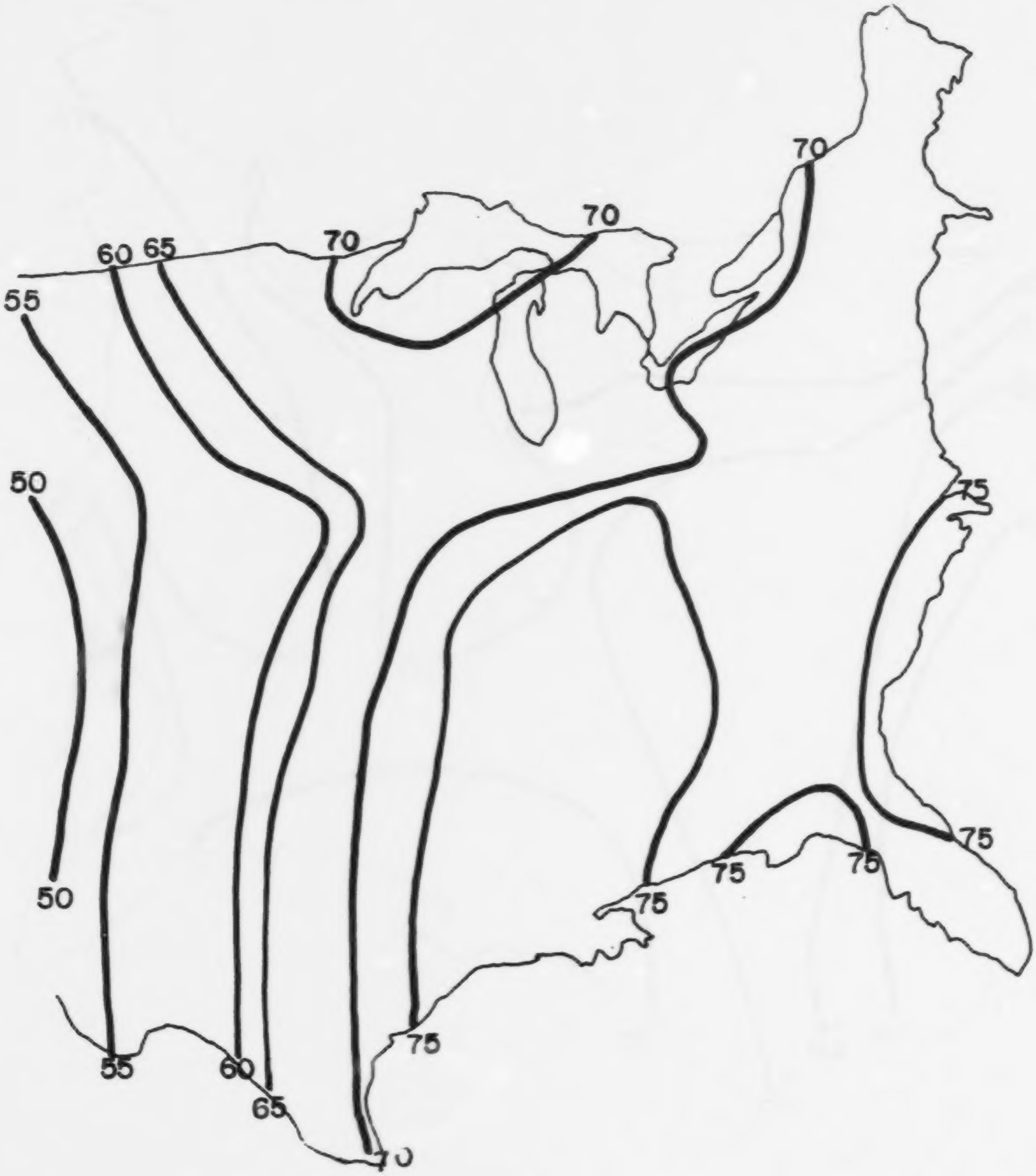
55
60
70
75

Figure 50. Seasonally averaged relative humidity over the eastern United States for the cold season.



70
70
70
60
65
55
50
75
75
75
75
75
50
55
60
65

Figure 51. Seasonally averaged relative humidity over the eastern United States for the warm season.

$$C_2 = C_{20}\exp[-\lambda_{d_2} + k_{p_2})t]$$

$$+ \frac{3}{2}\frac{C_{10}}{(\lambda_{d_2} + k_{p_2}) - (\lambda_{d_1} + k_{p_1} + K)}\Big\{\exp[-(\lambda_{d_2} + k_{p_2})t]$$

$$- \exp[-(\lambda_{d_1} + k_{p_1} + K)t]\Big\} \qquad (24)$$

where C_{10} and C_{20} are initial concentrations of SO_2 and sulfate, respectively. Since we assumed that sulfate is produced only by the transformation of SO_2, $C_{20} = 0$. Therefore,

$$C_2 = \frac{3}{2}\frac{C_{10}}{(\lambda_{d_2} + k_{p_2}) - (\lambda_{d_1} + k_{p_1} + K)}\Big\{\exp[-(\lambda_{d_2} + k_{p_2})t]$$

$$- \exp[-(\lambda_{d_1} + k_{p_1} + K)t]\Big\} \qquad (25)$$

The concentrations C_1 and C_2 computed from Eqs. (23) and (25) are shown in Fig. 52. According to this figure, the e-folding residence time of SO_2 T_{SO_2}, can be defined as

$$T_{SO_2} = \frac{1}{\lambda_{d_1} + k_{p_1} + K} \qquad (26)$$

The time T_m at which the concentration of sulfate, C_2, reaches a maximum, C_{2m}, can be calculated from

$$\frac{dC_2}{dt} = 0.$$

$$\frac{3}{2}\frac{K\,C_{10}}{(\lambda_{d_1} + k_{p_1} + K) - (\lambda_{d_2} + k_{p_2})}\Big\{-(\lambda_{d_2} + \lambda_{p_2})\cdot\exp[-(\lambda_{d_2} + k_{p_2})t]$$

$$+ (\lambda_{d_1} + k_{p_1} + K)\cdot\exp[-(\lambda_{d_1} + k_{p_1} + K)t]\Big\}$$

$$= 0$$

Therefore,

$$T_m = -\frac{1}{(\lambda_{d_1} + k_{p_1} + K) - (\lambda_{d_2} + k_{p_2})}\ln\frac{\lambda_{d_2} + k_{p_2}}{\lambda_{d_1} + k_{p_1} + K} \qquad (27)$$

The maximum concentration of sulfate, C_{2m}, is given by

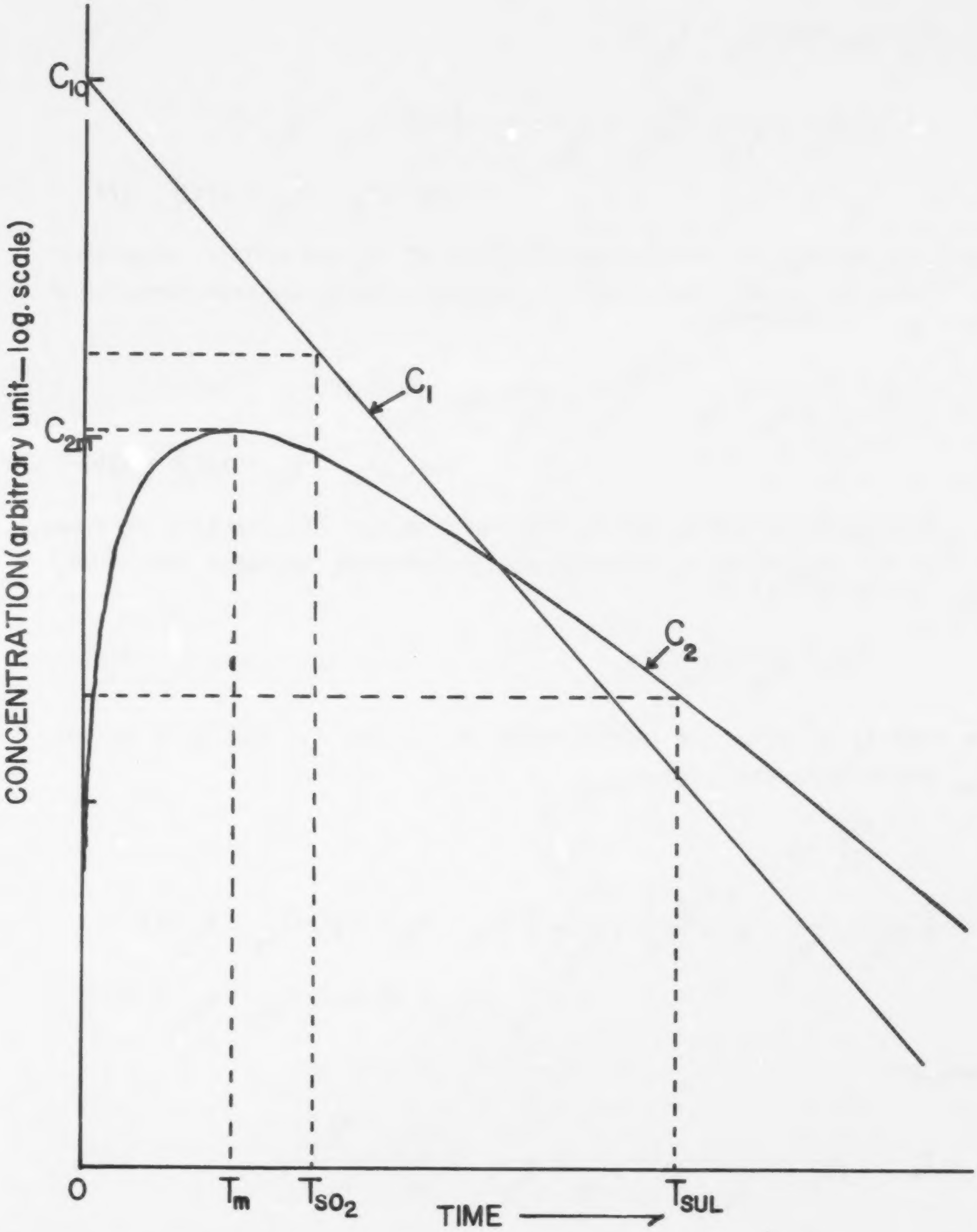


Figure 52. Schematic plot of the concentrations of SO_2 and sulfate as a function of time.

$$C_{2m} = \frac{3}{2} \frac{K}{(\lambda_{d_1} + k_{p_1} + K) - (\lambda_{d_2} + k_{p_2})} C_{10}$$

$$\cdot \exp\left(\frac{\lambda_{d_1} + k_{p_1} + K}{(\lambda_{d_1} + \lambda_{p_1} + K) - (\lambda_{d_2} + \lambda_{p_2})} \ln \frac{\lambda_{d_2} + k_{p_2}}{\lambda_{d_1} + \lambda_{p_1} + K} \right)$$

$$\cdot \left[\exp \left\{ - \left(\ln \frac{\lambda_{d_1} + k_{p_1} + K}{\lambda_{d_2} + \lambda_{p_2}} \right) \right\} -1 \right] \qquad (28)$$

We define the residence time of sulfate T_{sul} as the time elapsed until the concentration of sulfate, C_2, becomes $e^{-1} \cdot C_{2m}$. Therefore,

$$\frac{C_2}{C_{2m}} = \frac{\exp\left[-(\lambda_{d_1} + k_{p_1} + K)\, T_{sul}\right] \cdot \left[\exp\{(\lambda_{d_1} + k_{p_1} + K) - (\lambda_{d_2} + k_{p_2})\} T_{sul} - 1\right]}{\exp\left[\frac{\lambda_{d_1} + k_{p_1} + K}{(\lambda_{d_1} + k_{p_1} + K) - (\lambda_{d_2} + k_{p_2})}\right] \cdot \left[\exp \left\{ - \left(\ln \frac{\lambda_{d_1} + k_{p_1} + K}{\lambda_{d_2} + k_{p_2}} \right) \right\} - 1\right]}$$

$$= e^{-1} \qquad (29)$$

Equation (29) is solved numerically with iteration methods.

7.3.2 Chemical Transformation

There are several observational studies available on the transformation rate of SO_2 to sulfate. Unfortunately, the studies conducted in the field reveal a variability of the transformation rate over three orders of magnitude, depending on the concentrations of the plume, relative humidity, etc. In this study we are interested in the fates of SO_2 and of sulfate after both pollutants have been uniformly mixed in the mixing layer. For this reason, the observational data of the concentrations of SO_2 and sulfate taken at least one hour after emissions were scrutinized, and the transformation rates were plotted in Fig. 53 as a function of relative humidity. From this figure, the transformation rate K is derived as

$$K = 3.304 \times 10^{-4} \cdot \exp(0.063 \cdot RH) \ \ hr^{-1} \qquad (30)$$

where RH is the relative humidity in percent.

In previous studies (Henmi et al., 1977 and 1978), a constant value of $1 \times 10^{-6} sec^{-1}$ was used for the transformation rate. In the present study, the relationship of Eq. 30 was used.

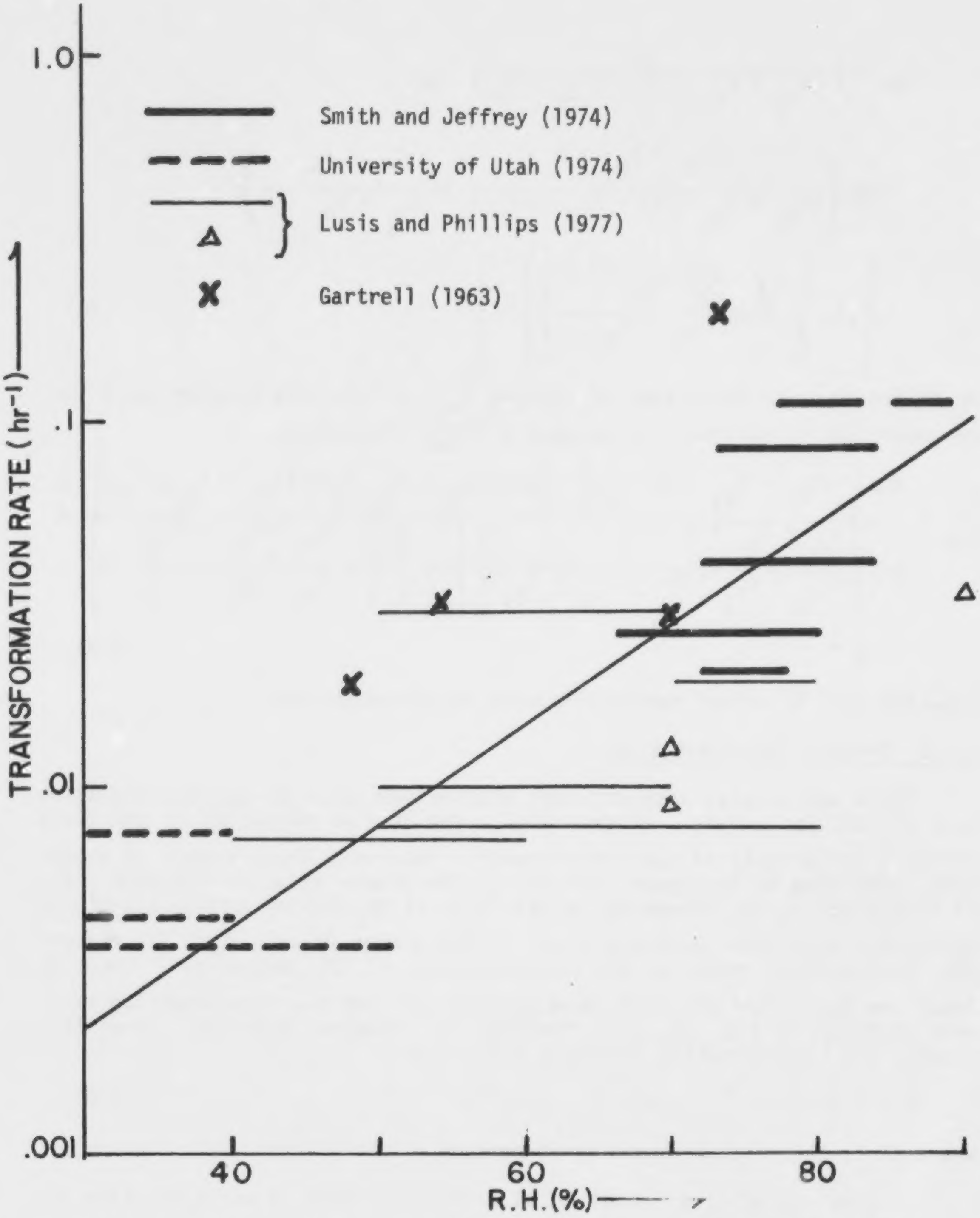


Figure 53. Transformation rate of SO_2 to sulfate as a function of relative humidity.

7.3.3 Dry Deposition and Precipitation Scavenging

Deposition velocities for SO_2 have been observed by a number of investigators. In the previous study, we reviewed several reports and assumed that, for our purpose, the dry deposition velocity of SO_2 is 1 cm/sec regardless of the region and the season. Little is known about the deposition velocity of sulfate. The only known measurements of sulfate deposition velocity in the atmosphere yielded approximately 0.1 cm/sec (Engelman and Sehmel, 1976).

Accordingly, the values

$$V_{g_1} = 1 \text{ cm/sec}$$

$$Vg_2 = 0.1 \text{ cm/sec}$$

were used in the present study. Here, V_g, is the deposition velocity of SO_2 and V_{g_2} is that of sulfate.

The depletion rate λ_d due to dry deposition can be written as

$$\lambda_d = \frac{V_g}{\bar{H}}$$

where $\bar{H}$ is the mean mixing layer height.

The scavenging rate due to precipitation, λ_p, can be expressed as

$$\lambda_p = \left(\frac{\kappa}{\chi}\right)_v \cdot \frac{\bar{P}}{\bar{H}} = \frac{\bar{V}_S}{\bar{H}}$$

where κ is the concentration of SO_2 or $SO_4^{=}$ in rainwater, χ the concentrations of those pollutants in air, and $\bar{P}$ the mean precipitation rate during a precipitation event. The subscript v means that the ratio (κ/χ) is formed on a volume basis. The depletion rate due to precipitation, k_p, is given by

$$k_p = f \cdot \lambda_p$$

where f is the probability of precipitation events. It can be expressed by

$$f = \frac{\tau_p}{\tau_d + \tau_p}$$

τ_p is the length of the average wet period and τ_d is the length of the average dry period. Data of τ_p and τ_d were shown by Henmi et al. (1977 and 1978).

Values of $(\frac{K}{X})_v$ for SO_2 have been scrutinized in our previous report, and the value of 5×10^4 has been chosen as typical. We have little knowledge about the value of $(\frac{K}{X})_v$ for sulfate. Therefore, in this study we assume, tentatively, the value of 5×10^4 for that pollutant to be identical with that for SO_2.

7.4 RESULTS

The regional residence times of SO_2 in hours, T_{SO_2}, for the cold and warm seasons are shown in Figs. 54 and 55. The regional residence times of sulfate in hours, T_{SUL}, for the cold and warm season are given in Figs. 56 and 57.

The following can be seen from these diagrams:

1. Both T_{SO_2} and T_{SUL} are longer in the warm season than in the cold season over the whole region studied. This is due to shorter dry periods and shallower mixing layers in the cold season than in the warm season.

2. Short residence times characterize the region surrounding the Great Lakes and the coastal regions.

3. Values for T_{SO_2} and T_{SUL} are found to be relatively long in the western parts of the area under investigation, where the mixing layer height is large, the precipitation frequency is small and the relative humidity is small.

4. The regional residence times of SO_2, T_{SO_2}, are in the range between 15 and 30 hours for the cold season and in the range between 15 and 40 hours for the warm season. T_{SO_2} in the present study is shorter than the values derived in the previous study. The reason for this difference is that in the previous study a constant value of 1×10^{-6} sec^{-1} for the transformation rate was used.

5. The regional residence time of sulfate, T_{SUL}, defined in the present study is about one order of magnitude greater than T_{SO_2}. Values for T_{SUL} are in the range between 150 and 450 hours for the cold season and in the range between 200 and 500 hours for the warm season.

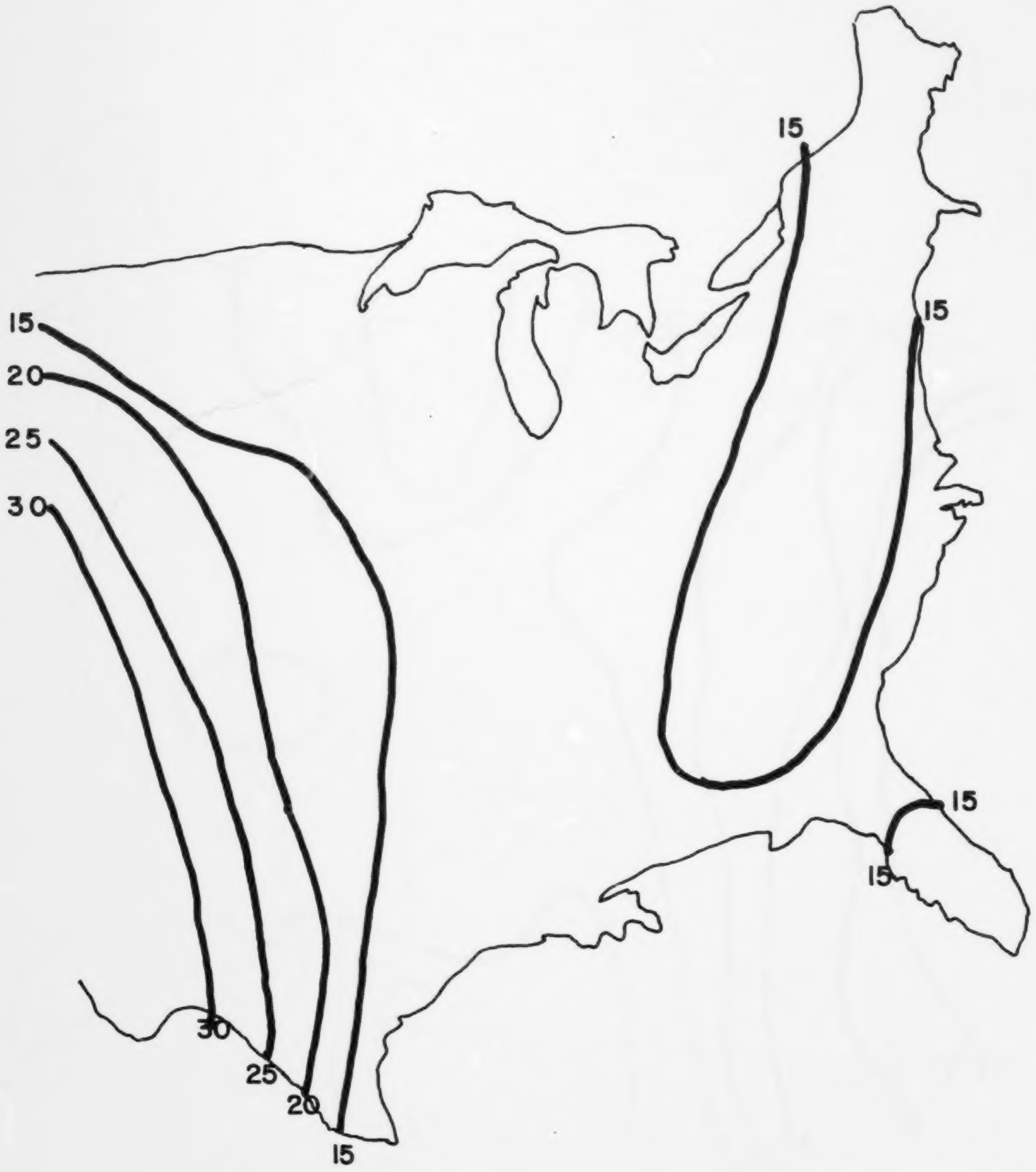
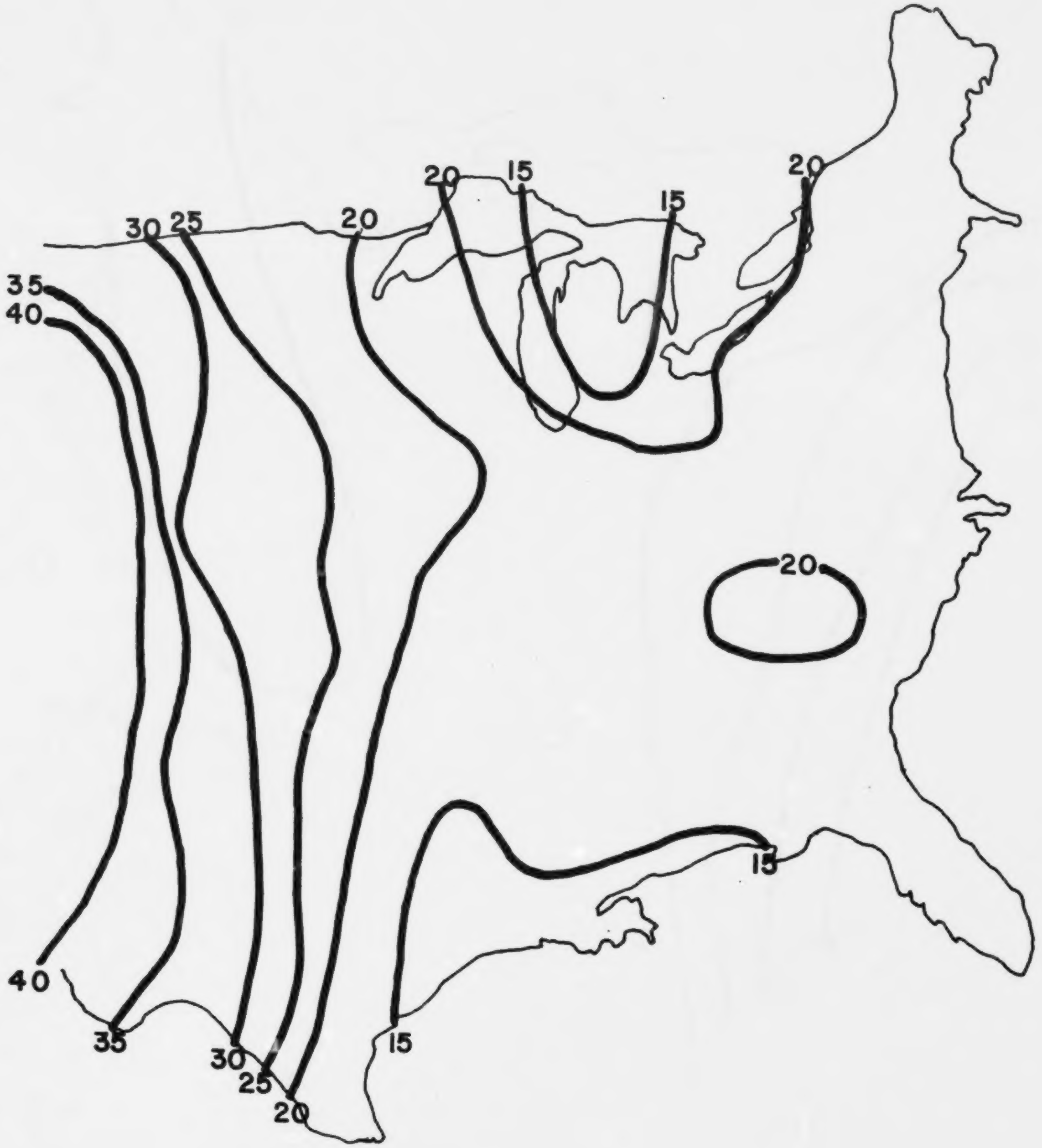

15
15
15
20
25
30
30
25
20
15
15
15

Figure 54. The regional residence time of SO_2 in hours, T_{SO_2}, for the cold season.



20
15
15
20
30
25
20
35
40
20
15
40
35
30
25
20
15

Figure 55. The regional residence time of SO_2 in hours, T_{SO_2}, for the warm season.

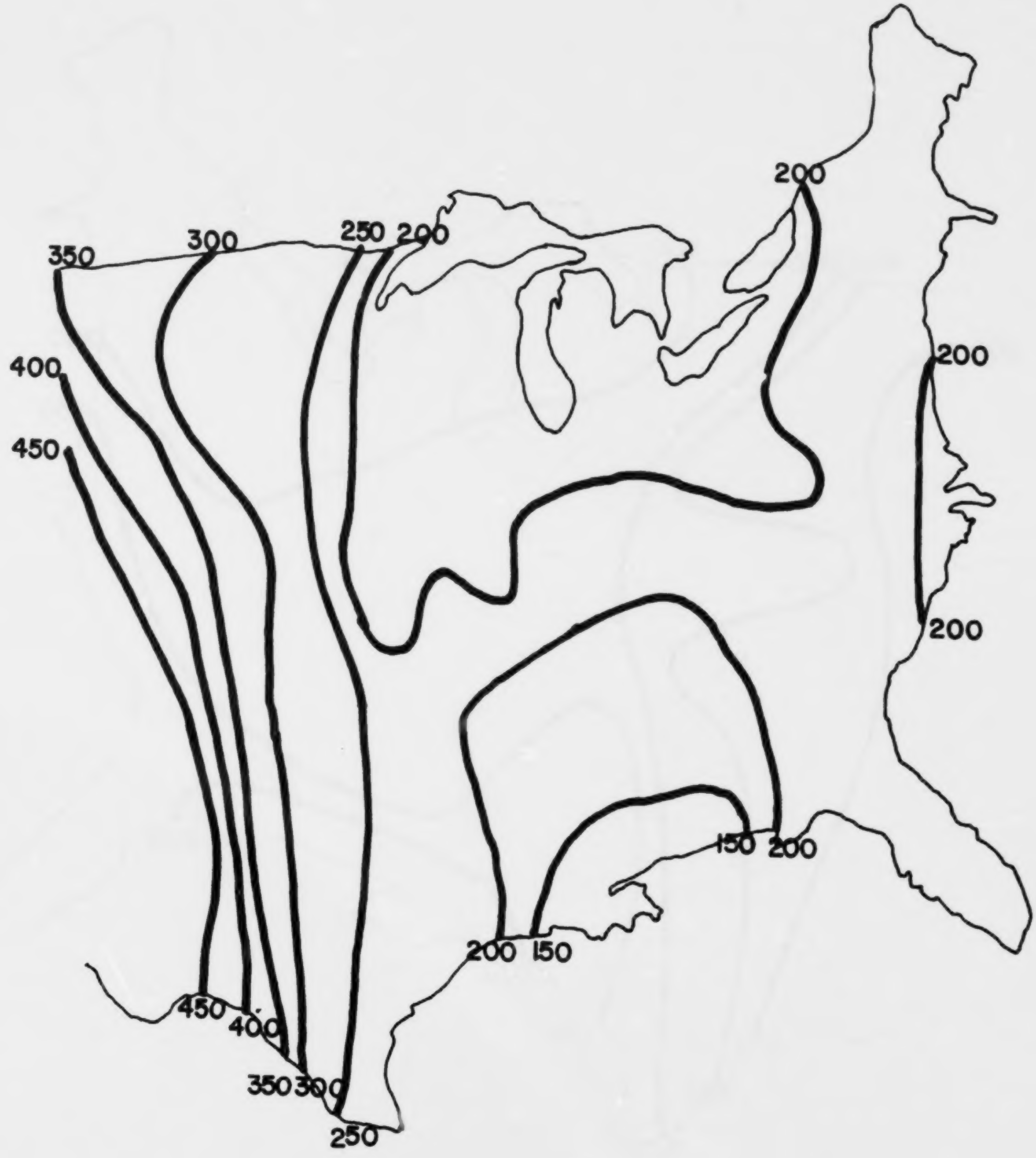

350
300
250
200
200
200
200
400
450
150
200
200
150
450
400
350
300
250

Figure 56. The regional residence time of sulfate in hours, T_{SUL}, for the cold season.

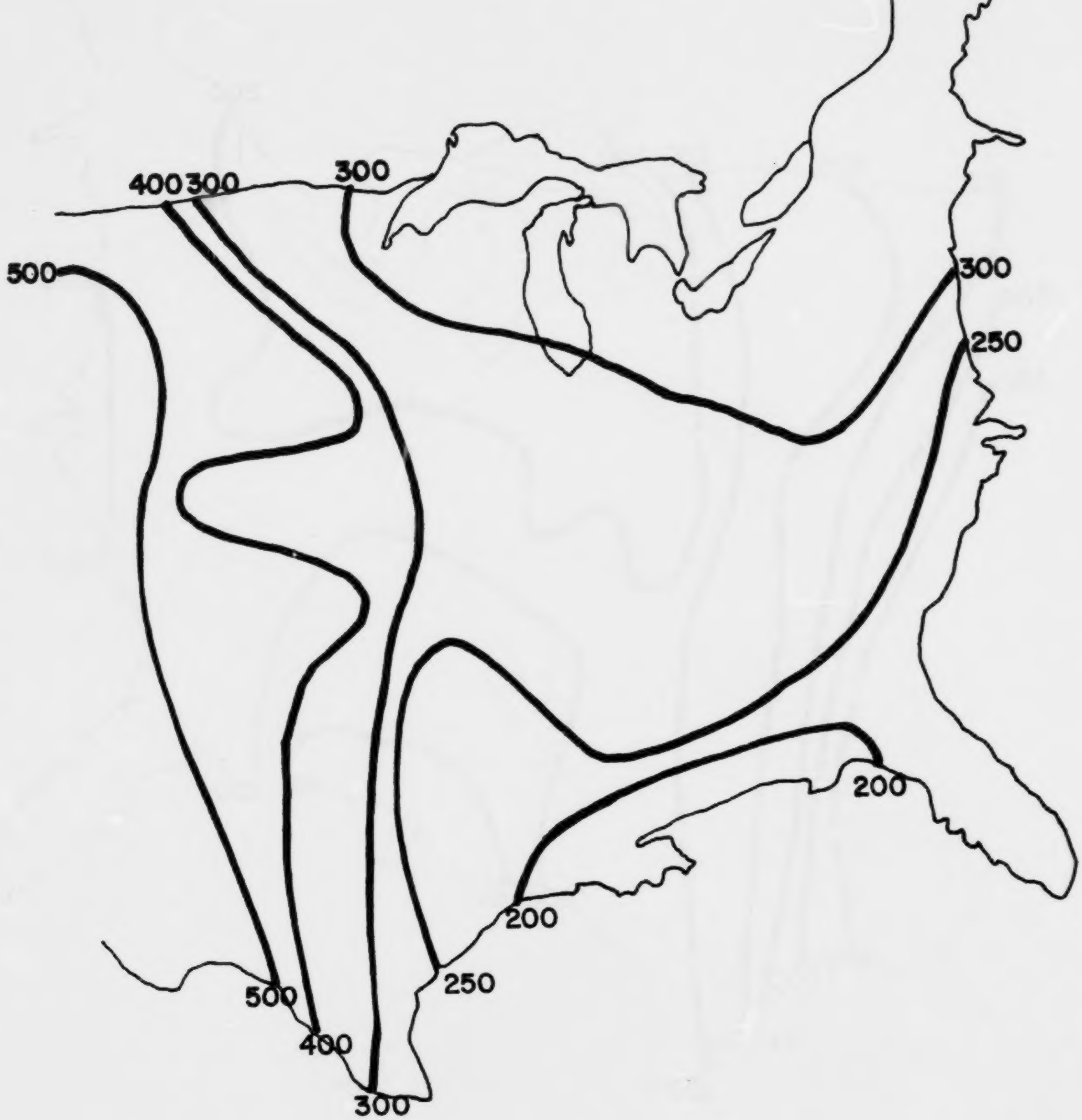

400
300
300
500
300
250
200
200
250
500
400
300

Figure 57. The regional residence time of sulfate in hours, T_{SUL}, for the warm season.

7.5 SENSITIVITY ANALYSIS

As can be seen from Eqns. (26) and (29), the residence times of SO_2 and sulfate are dependent on several physical parameters whose values are determined empirically or experimentally. These parameters include the dry deposition velocity of SO_2, Vg_1, the dry deposition velocity of sulfate, Vg_2, the transformation rate of SO_2 to sulfate, K, and the dimensionless ratios of SO_2 and sulfate contents in rainwater and air, $(\frac{K}{X})_{SO_2}$ and $(\frac{K}{X})_{SO_4}$. The actual values of these parameters may be different from those used in our calculations of residence time. Thus, it is necessary to perform sensitivity analyses by varying systematically the values of these parameters.

For each parameter, calculations were made with values varying about the reference value, whereas the other parameters remain at their reference values. Changes in residence times of SO_2 and sulfate are given in Table 9. The changes of residence times given in this table are based on climatological data for the cold season obtained at Charleston, West Virgina. Calculations for several stations show a similar range of changes in residence times.

This table also indicates that the residence times change substantially with the changes of these parameters. Therefore, we must regard our results as approximate until better knowledge about these parameters is obtained.

7.6 SUMMARY

In this study, we have extended a previous investigation of the regional residence times of SO_2, using an empirical relationship between the transformation rate K and the relative humidity. The residence time of sulfate, T_{SUL}, was defined mathematically and T_{SUL} was also calculated over the region of the United States east of 105°W longitude where major industrial activities are located.

The residence times of SO_2 and sulfate were calculated over the region of the United States east of 105°W longitude where major industrial activities are located. The regional residence times of SO_2 are in the range between 15 and 30 hours for the cold season and in the range between 15 and 40 hours for the warm season.

The regional residence time of sulfate is about one order of magnitude greater than that of SO_2, ranging between 150 and 450 hours for cold season and between 200 and 500 hours for the warm season.

TABLE 9. SENSITIVITY ANALYSES FOR PARAMETERS

Parameter	Reference Value	Value Used	Change in SO_2 Residence Time	Change in SO_4 Residence Time	The Values of Other Parameters
Transformation rate of SO_2 to SO_4	0.0257/hr	.00257/hr	+ 30%	+ 26%	Vg_1 = 1cm/sec
		.257/hr	- 70%	- 32%	Vg_2 = 0.1cm/sec
K					$(\frac{K}{X})SO_2 = 5\text{x}10^4$ $(\frac{K}{X})SO_4 = 5\text{x}10^4$
Dimensionless ratio of SO_2 and SO_4 contents in rain and air	$5\text{x}10^5$	$5\text{x}10^4$	+ 66.6%	+ 308.2%	Vg_1 = 1 cm/sec
		$5\text{x}10^6$	-79.0%	- 86.5%	Vg_2 = 0.1 cm/sec
$(\frac{K}{X})SO_2$, $(\frac{K}{X})SO_4$					K = 0.0257/hr
Deposition	0.1cm/sec	0.2cm/sec	0.0%	-2.9%	Vg_1 = 1cm/sec
velocity of SO_4		0.3	0.0%	-5.7%	
		0.4	0.0%	-8.5%	$(\frac{K}{X})SO_2 = 5\text{x}10^4$
Vg_2		0.5	0.0%	-11.2%	$(\frac{K}{X})SO_4 = 5\text{x}10^5$ K = 0.0257/hr
Deposition	1cm/sec	2cm/sec	-23.0%	-8.5%	Vg_2 = 0.1cm/sec
velocity of SO_2		3cm/sec	-37.0%	-15.7%	$(\frac{K}{X})SO_2 = 5\text{x}10^4$
Vg_1					$(\frac{K}{X})SO_4 = 5\text{x}10^5$ K = 0.0257/hr

CHAPTER 8

NUMERICAL STUDY ON SULFATE CONTENT IN RAINWATER

8.1 INTRODUCTION

The extent, severity, and causes of acid precipitation are becoming topics of major concern in the United States. In Europe it was reported many years ago that the acidification of lakes and rivers in Scandinavia was caused mainly by long-range transport of pollutants from Britain and from the European continent. Acid rain in the northeastern United States is associated with air parcels that have travelled through major industrial areas in the midwestern and east-central states.

Acid rains, associated with sulfate pollution, cause structural, agricultural and ecological damage. Because of this potential damage, it is important to predict accurately air and water quality under future use of fuels with high sulfur content.

Reliable continuous precipitation chemistry data for the United States are sparse. However, several attempts have been made to determine the chemical composition of rain. Junge and Werby (1958) measured the concentrations of chloride, sodium, potassium, calcium, and sulfate in rainwater over the United States. Average sulfate concentrations over the United States were in the range of 1 mg/liter to 5 mg/liter. Recent studies in a region surrounding the St. Louis area (Hales and Dana, 1979) show the extremely wide variability in chemical content from one event to another. However, the average sulfate content of rainwater is in the range between 4 mg/liter and 17 mg/liter. Sulfate concentrations in rainwater observed in Ithaca, N.Y., and Aurora, N.Y., are within the range of 1 to 8 mg/liter (Dittenhoefer and Dethier, 1976). Thus, it may be concluded that, although the sulfate content of rainwater varies with storm type, trajectory of air mass, geoprahical location, etc., it is within the range of 1 to 20 mg/liter.

Recently, Scott (1978) has proposed that sufficient sulfate aerosol exists to account for observed levels of sulfate in rainwater. According to Scott, sulfate formation from sulfur dioxide in cloud water and rainwater is not fast enough to produce appreciable quantities of sulfate during the lifetime of the cloud particles contributing to precipitation.

The concentration of sulfate in precipitation is a consequence of several microphysical processes occurring within and beneath the clouds. Microphysical processes such as Brownian motion, attachments due to thermophoresis and diffusiophoresis, inertial impaction and nucleation serve to remove the sulfate aerosol from the air.

The purpose of this chapter is to examine the validity of Scott's idea. Taking into consideration the microphysical processes mentioned above, model calculations of rainout processes of sulfate aerosols were carried out.

8.2 THE CLOUD MODEL

In the case of a precipitating cumulus cloud, the discrete particle sizes of importance range from aerosol particles of the order of 10^{-3} micrometers in diameter to precipitation drops as large as 5×10^3 micrometers in diameter. Therefore, in order to study the interaction of pollutant particles and cloudwater droplets, a model must be chosen in which the microphysical processes are incorporated in as much detail as possible. One such model is the one-dimensional cumulus model by Cotton (1972a, b). This model involves upward integration with height following the rise of the convective bubble or plume.

A numerical model which is composed of cloud dynamics and microphysics of cloud particles and aerosol has been developed (Henmi et al., 1977, 1978). In this model, the aerosols in the planetary boundary layer are transported up into the cumulus cloud. The cloud is envisaged as an assembly of cloudwater droplets and rainwater droplets intermingled with aerosol pollutants, some of which are free-floating in the cloud air and some are collected by the droplets. This model is used for the present calculations to estimate the amount of aerosol pollutants captured by cloudwater and rainwater droplets.

8.3 SULFATE AEROSOLS IN THE ATMOSPHERE

Atmospheric aerosol is composed of "fine" particles having a diameter smaller than 2 micrometers and "coarse" particles having a diameter greater than 2 micrometers. Those fine and coarse modes are usually quite different in chemical properties. The physical separation of the fine and coarse modes is justified because the condensation process produces fine particles whereas mechanical processes produce mostly coarse particles. Practically all of the sulfate found in atmospheric aerosol is in the fine mode (Whitby, 1978).

According to Whitby (1978), on the average, the sulfate content of continental aerosol is 15 to 30 percent of the total aerosol mass, whereas marine aerosols contain sulfate in the range of 30 to 60 percent.

In Fig. 58 the size distributions of typical urban aerosol and background aerosol are shown. The mass concentrations of urban aerosol and background aerosol given in this figure are $99.6\ \mu g/m^3$ and $48.7\ \mu g/m^3$, respectively. The accumulation modes contain $61.3\ \mu g/m^3$ and $18.7\ \mu gm^3$, of urban aerosol and background aerosol. For the present study, we assume that 50 percent of the mass of aerosol in the accumulation mode is composed of sulfate.

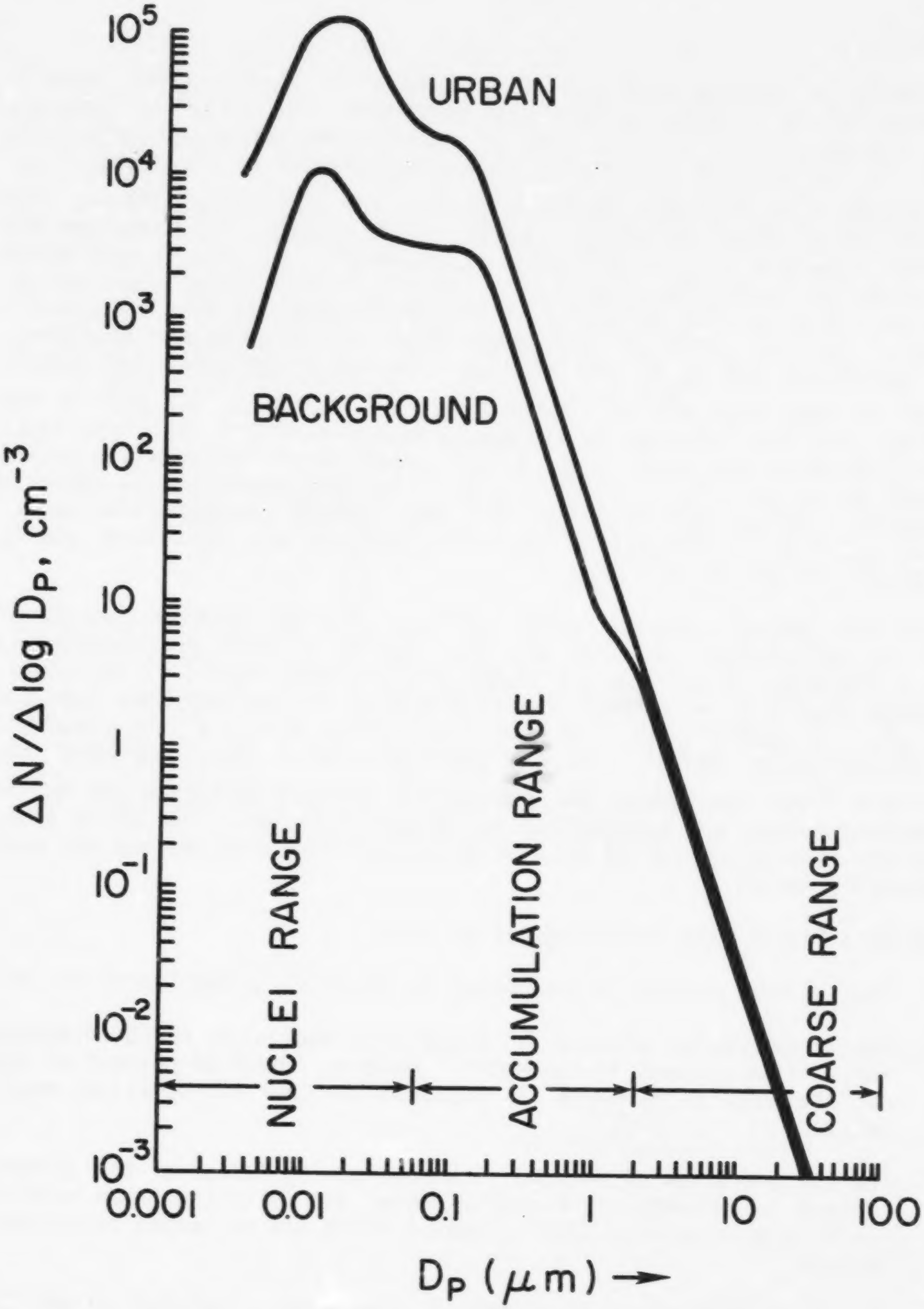


Figure 58. Size distributions of typical urban and background aerosols (Whitby, 1978).

8.4 RESULTS

Following the procedures described by Henmi et al. (1977, 1978), numerical calculations of cumulus clouds are performed. In order to generate different clouds, different input data of sounding and entrainment constants are used. In the present calculation, the concentration of cloudwater droplets is assumed to be 300 cm^{-3}, which is typical for continental clouds. The theoretical calculations by Howell (1949), Mordy (1960), and Neiburger and Chien (1960) show that the concentration of cloudwater droplets is determined by the number of effective condensation nuclei in the cloud base region. Furthermore, the particles effective as condensation nuclei are, in general, hygroscopic. Sulfate particles are known to be very hygroscopic (Fletcher, 1966). Therefore, two cases are studied. In the first case, the simple assumption is made that the 300 largest aerosol particles per cm^3 in the accumulation mode are consumed as condensation nuclei within the first layer of integration above the cloud base. In the second case, condensation nuclei are assumed to be supplied by other sources. Sulfate particles are captured by cloudwater droplets and rainwater droplets through microphysical mechanisms such as Brownian diffusion, inertial impaction and attachment due to thermophoresis and diffusiophoresis.

Using the aerosol spectra shown in Fig. 58, the sulfate content of rainwater is calculated. In Fig. 59, the sulfate content of rainwater is shown as a function of the average liquid water content (LWC) of the cloud. This average liquid water content is calculated as a value averaged over the cloud height. In general, LWC is proportional to the height of the cloud and to the precipitation amount. In Fig. 59 the broken lines represent the result of the first case where the 300 largest aerosol particles per cm^3 in the accumulation mode are consumed as condensation nuclei. The solid lines represent the results of the second case where sulfate particles are not used as condensation nuclei.

From this figure, the following can be seen:

i) The sulfate content in rainwater is inversely proportional to LWC.

ii) The condensation process is a dominant mechanism for determining the sulfate content in rainwater. However, about 60 percent of the sulfate mass in rainwater is captured by other microphysical mechanisms.

iii) The concentration of aerosol is a determining factor of the sulfate content in rainwater. Rainwater which has collected urban aerosol contains more sulfate than rainwater which has collected background aerosol.

iv) The sulfate content of rainwater from these simulated clouds is within the range of 1 and 8 mg/l. These values are well within the range suggested by observations.

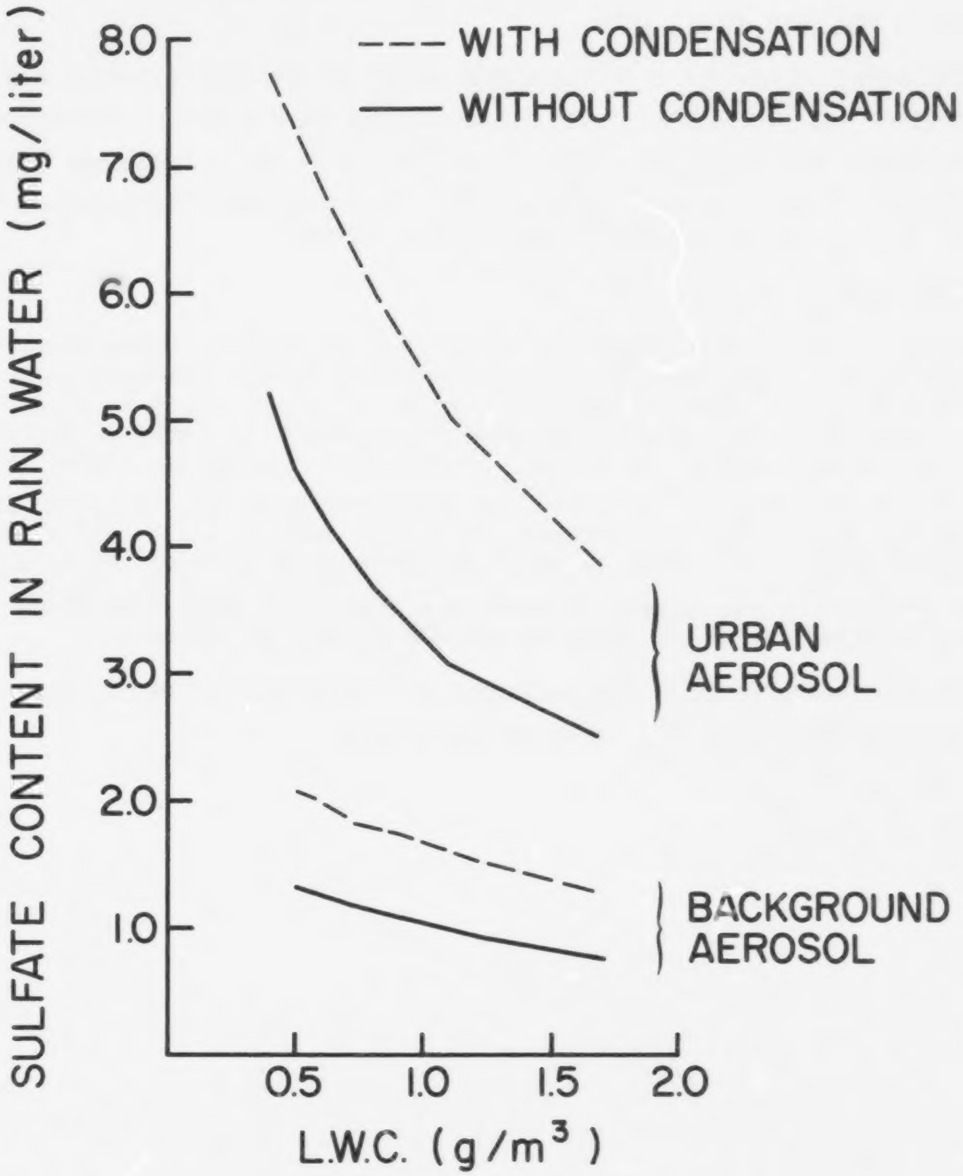


Figure 59. Sulfate content of rainwater as a function of L.W.C. of the cloud.

Figure 60 shows the relationship between (κ/χ) and LWC, where (κ/χ) is the dimensionless ratio of pollutant concentrations in rainwater and air. (κ/χ) is inversely proportional to LWC. Hales and Dana (1979) derived a similar relationship as

$$(\frac{\kappa}{\chi}) = 1.9\text{x}10^6 A^{-0.88}$$

where, A is the rain amount (cm).

Similarly, an inverse relationship between ($\frac{\kappa}{\chi}$) and precipitation amount, precipitation rate or LWC has been found by Engelmann (1971). The observations by Scott and Lanlainen (1979) show that (κ/χ) for sulfate was $7.9\text{x}10^5$ and $2.03\text{x}10^6$ in two different rain events. It seems that (κ/χ) values from our simulated clouds are close to the observed values.

8.5 CONCLUSION

Although the present study has shown that microphysical processes such as condensation, Brownian diffusion, attachment due to thermophoresis and diffusiophoresis and inertial impaction can be efficient enough to attain the sulfate content of rainwater, this conclusion should be regarded as tentative. The sulfate content of aerosol in the present study was assumed to be about 30 $\mu g/m^3$ and 9 $\mu g/m^3$ for urban and background aerosols. A recent study by Hales and Dana (1979) is contradictory to the study by Scott (1978) and to our present study. According to Hales and Dana, a rapid oxidation of SO_2 to sulfate occurs in cloud systems in warm, polluted environments and leads to a possible explanation for the observed sulfate content of rainwater.

The combined effects of the microphysical processes and of SO_2 oxidation to sulfate in water must be studied in the future.

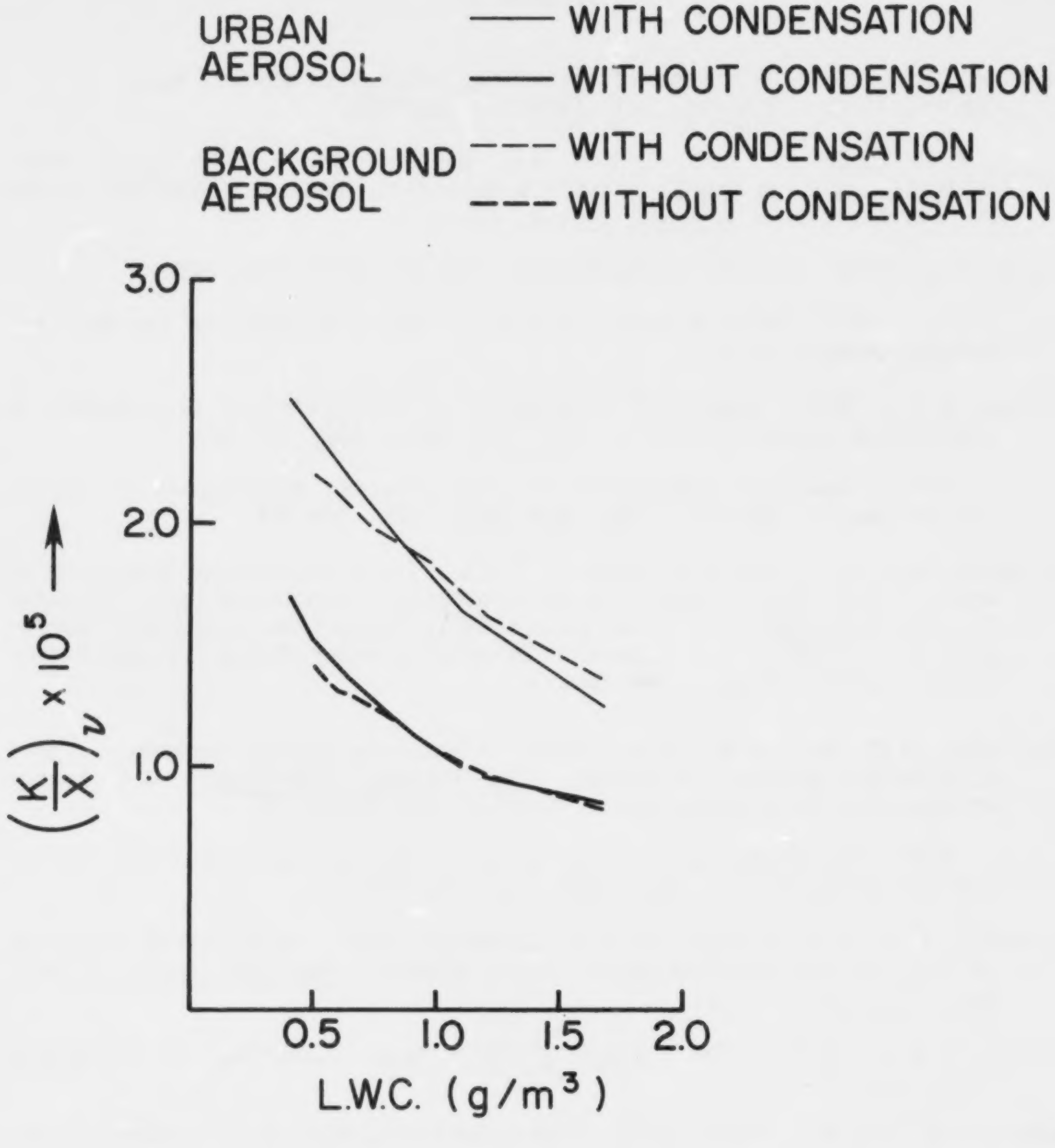


Figure 60. $(\frac{K}{X})_V$ as a function of L.W.C. of the cloud.

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APPENDIX - A

FORTRAN LISTING OF MODEL A

Trajectory Calculation Program (Model A)

```
     PROGRAM TRAJET
     COMMON /STAT/ SLAT(100,4,8), SLON(100,4,8), XAW(100,4,8),
    Z YAW(100,4,8), XSIGMA(100,4,8), YSIGMA(100, 4,8)
**FORWARD AND BACKWARD TRAJECTORY MODEL
**USING OBSERVED AND ANALYZED INPUT WINDS

     LOGICAL SICNT
**FOR OBSERVED INPUT WINDS ONLY****************************************
     DIMENSION SLATT(100), SLONT(100), XAWT(100), YAWT(100)
     DIMENSION NSTA(4, 8)
     DIMENSION XXSIG(100), YYSIG(100)
     INTEGER SID(100, 4)
     INTEGER TSLAT,TSLON
**SEE DATA MXNSTA
***********************************************************************
***********************************************************************
     LOGICAL SJTAG(5),SICNTT
     INTEGER XIP(30),YIP(30),XTSIP(30),YTSIP(30),WIP(30)
     DIMENSION OID(5),OLAT(5),OLON(5)
     DIMENSION WIOHOT(5)
     INTEGER DXSIGP(30),DYSIGP(30)
     COMMON/INPUT1/IBDY,IBMO,IBYR,NDY,TDIR,
    A          POLLAT,IHOUR,IMO,
    A         NDYDUR,NDYDTA,WTYPE,DTABT,DTABB,DTABL,DTABR,
    A     LBAAT,LTAAT,ALATT,ALATB,ALONL
**MAXIMUM NUMBER OF ORIGINS
     DATA MXNO/5/
**MAXIMUM NUMBER OF STATIONS
     DATA MXNSTA/100/
     DATA OBS,ANA/3HOBS,3HANA/
     DATA BACK/4HBACK/
     DATA SJTAG/1H ,1H.,1H+,1H*,1H-/
     DATA ITS,ITPDY,IMM/20, 4, 8/
     ISNAP=0
     CALL   INPUT   ( NTPDY, TSDUR, RADIUS, ICNTMN, ICNTMX, MBIP, MEIP,
    Z MXNO, NO, OID, OLAT, OLON, WIOHOT, IHRINP, NLVLA, NTSPDY,
    Z NTS, NMM)
**SET ITAB FORWARD/BACKWARD TO 1 FOR FORWARD, 2 FOR BACKWARD
     ITABFB=1
     IF (TDIR .EQ. BACK) ITABFB=2

**LOOP THROUGH NUMBER OF DAYS
     DO 400 M=1,NDY
     CALL   DTABKO   ( M, MXNSTA, NTPDY, NMM, NSTA, ITABFB, NDYDTA,
    Z ITPDY, IMM, DTABT, DTABB, DTABL, DTABR, LBAAT, LTAAT, OLAT(1),
    Z OLON(1), SID)

**LOOP THROUGH NUMBER OF ORIGINS
     DO 399 IO=1,NO

**LOOP THROUGH NUMBER OF TRAJECTORIES PER DAY
     DO 300 K=1,NTPDY
     IF (ITABFB .EQ. 2) GO TO 32
     MM=1
     KK=1
     GO TO 33
 32  MM=NMM
     KK=4

**LOOP THROUGH NUMBER OF TRAJECTORY SEGMENTS
 33  DO 299 J = 1, NTS
     IF(J.EQ.1) GO TO 40
     IF (TSLAT .LE. 900) GO TO 42
**TRAJECTORY HAS BEEN TERMINATED
**DUE TO INSUFFICIENT AMOUNT OF INPUT DATA-
**TERMINATION CODE INFORMATION
**REPLACES ALL REMAINING TRAJECTORY SEGMENT LAT,LON VALUES
```

```
      GO TO 200
   40 TSLAT1=OLAT(IO)
      TSLON1=OLON(IO)
      SPRED=0.
      SPRED1=0.
   42 JTAG=0
      CALL    KKMM    ( J, K, M, KK, MM, NMM, NDYDTA, NTSPDY,ITABFB,IRTNS)
      IF (IRTNS .EQ. 90) GO TO 90
**TRAJECTORY TERMINATED DUE TO NO DATA READ INTO DATA-BLOCK(DTABK)
**OR CLOSEST-TIME(CLSTM) CALCULATION OUTSIDE DATA-BLOCK
   86 TSLAT = 996
      TSLON=9996

      UBAR=0.
      SPREAD=0.
      ALPHA=99.
      BETA=99.
      T=99.
      R2=99.
      IJK=0
      ICNT=0
      SICNT=SJTAG(1)
      GO TO 200
   90 CALL    DISO    ( J, K, M, KK, MM, MXNSTA, NSTA, ITABFB,
     A  ITS, ITPDY, IMM, RADIUS, TSDUR, MBIP, MEIP, SLATT, SLONT, TSLAT1
     A, TSLON1, XAWT, YAWT, XXSIG, YYSIG, KKT, MMT, SJTAG, JTAG, ICNTMN,
     A ICNTMX, XIP, YIP, XTSIP, YTSIP, DXSIGP, DYSIGP, WIP, TSLAT2,
     A TSLON2, ISNAP, WIOROT(IO), UBART, SIGMAH, ICNTT, SICNTT, SPRED1,
     A SPRED2, ALPHAA, BETAA, TA, R2A, IJKA, IRTNS)
      IF (IRTNS .EQ. 170) GO TO 170
      CALL    ALTDTA    ( SJTAG, JTAG, TSLAT2, TSLON2, UBART, SIGMAH,
     Z ICNTT, SICNTT, ALPHAA, BETAA, TA, R2A, IJKA, IRTNS)
      IF (IRTNS .EQ. 170) GO TO 170
  140 CALL    CLSTM    ( J, KK, MM, JTAG, NTPDY, ITABFB, M, NDYDTA, NMM,
     Z KKT, MMT, IRTNS)
      IF(IRTNS .EQ. 90) GO TO 90
      IF(IRTNS .EQ. 86) GO TO 86
  170 TSLAT=TSLAT2*10.+.5
      TSLON=INT(TSLON2*10.+1800.5)-1830
      UBAR=UBART+.5
      ICNT=ICNTT
      SICNT=SICNTT
      TSLAT1=TSLAT2
      TSLON1=TSLON2
      SPRED1=SPRED2
      SPRED=SPRED+SIGMAH
      SPREAD=SPRED/60.
      ALPHA=ALPHAA
      BETA=BETAA
       T=TA
      R2=R2A
      IJK=IJKA
  200 KUNIT=20+IO
      WRITE(KUNIT) TSLAT, TSLON, UBAR, SPREAD, ALPHA, BETA, T, R2, IJK,
     Z ICNT, SICNT
      IF(TSLON .EQ. 9996) GO TO 300
  299 CONTINUE
  300 CONTINUE
  399 CONTINUE
  400 CONTINUE
**END OF TIME AND ORIGIN LOOPS

   WRITE TO A PERMANENT FILE THOSE VARIABLES WHICH
   WILL BE NEEDED BY THE SECOND PROGRAM.

      DO 475 I = 1, 5
          WRITE(14, 455)  OID(I), OLAT(I), OLON(I)
  475 CONTINUE
      WRITE(14, 480) NO, NDY, NTS, NTPDY, LTAAT
      WRITE(14, 490) TSDUR, ALATT, ALONL
  455 FORMAT (A3, F4.1, F6.1)
  480 FORMAT(5I10)
  490 FORMAT(3F15.5)
      STOP
      END



      SUBROUTINE ALTDTA(SJTAG, JTAG, TSLAT2, TSLON2, UBART, SIGMAH,
     Z ICNTT, SICNTT, ALPHAA, BETAA, TA, R2A, IJKA, IRTNS)

**ALTERNATE DATA SELECTION

      LOGICAL SJTAG(5),SICNTT
      DATA OBS,ANA/3HOBS,3HANA/
      IRTNS=0
      JTAG=JTAG+1
      IF (JTAG .LE. 4) RETURN
      JTAG=JTAG+1
      IF (JTAG .LE. 4) RETURN
      JTAGT=5
      TSLAT2=99.9
      TSLON2=999.9
      UBART=0.
      SIGMAH=0.
      ALPHAA=99.
      BETAA=99.
      TA=99.
      R2A=99.
      IJKA=0
      ICNTT=ICNTT
      SICNTT=SJTAB(JTAGT)
      IRTNS=170
      RETURN
      END


      SUBROUTINE AWIND(SHT, SATH, DI, LBAAT, LTAAT, WHT, XW, YW, NLVL,
     Z XAW, YAW, XSIGMA, YSIGMA)

**AVERAGE WINDS

      INTEGER SID,SHT,SATH,BTH,TTH,TH
      INTEGER     SHT,SATH,BTH,TTH,TH
      INTEGER WHT(50)
      DIMENSION XW(50),YW(50)
      DIMENSION MHT(100)
      LB=SHT+LBAAT
      IF (LBAAT .NE. 0 .OR. DI .GT. 60. .OR. SHT .GT. SATH)LB=SATH+LBAAT
      LT=SATH+LTAAT
      STHXW=0.
      STHYW=0.
      STH=0.
**CALCULATE M HEIGHTS FOR WIND LEVELS
      IF(NLVL.EQ.1) GO TO 21
      MLVL=NLVL*2-1
      DO 12 M=1,MLVL,2
      MHT(M)=WHT((M+1)/2)
   12 CONTINUE
**CALCULATE M HEIGHTS FOR MID LEVELS
      DO 14 M=2,MLVL,2
      MHT(M)=(MHT(M-1)+MHT(M+1))/2
   14 CONTINUE
**DETERMINE M LAYER FOR LB
      IF(LB.GE.MHT(1)) GO TO 18
      M=1
      GO TO 30
   18 DO 20 M=2,MLVL
      IF(LB.LT.MHT(M)) GO TO 30
   20 CONTINUE
   21 XAW=99.
      YAW=99.
      XSIGMA=99.
      YSIGMA=99.
      RETURN
**CALCULATE WEIGHT SUMS AT LB
   30 MLB=M
      BTH=MHT(M)-LB
        M1=(M+1)/2
      STHXW=STHXW+BTH*XW(M1)
      STHYW=STHYW+BTH*YW(M1)
      STH=STH+BTH
**DETERMINE M LAYER FOR LT
      IF(LT.LE.MHT(MLVL)) GO TO 48
      MM=MLVL
      GO TO 70
   48 MLVLM1=MLVL-1
      DO 50 M=1,MLVLM1



      MM=MLVL-M
      IF(LT.GT.MHT(MM)) GO TO 70
   50 CONTINUE
      XAW=99.
      YAW=99.
      XSIGMA=99.
      YSIGMA=99.
      RETURN
**CALCULATE WEIGHT SUMS AT LT
   70 MMLTM1=MM-1
      TTH=LT-MHT(MM)
       MM2=(MM+2)/2
      STHXW=STHXW+TTH*XW(MM2)
      STHYW=STHYW+TTH*YW(MM2)
      STH=STH+TTH
      IF(MLB.GT.MMLTM1) GO TO 300
**CALCULATE INTERMEDIATE WEIGHT SUMS
      DO 100 M=MLB,MMLTM1
      TH=MHT(M+1)-MHT(M)
       M2=(M+2)/2
      STHXW=STHXW+TH*XW(M2)
      STHYW=STHYW+TH*YW(M2)
      STH=STH+TH
  100 CONTINUE
  300 IF(STH.EQ.0.) STH=.00001
      XAW=STHXW/STH
      YAW=STHYW/STH
      XSIGMA=0.
      YSIGMA=0.
      DO 101 M=MLB,MMLTM1
      TH=MHT(M+1)-MHT(M)
      XSIGMA=XSIGMA+TH*(XW((M+2)/2)-XAW)**2
      YSIGMA=YSIGMA+TH*(YW((M+2)/2)-YAW)**2
  101 CONTINUE
      IF(XSIGMA.LT.0.0.OR.YSIGMA.LT.0.0) GO TO 500
      IF(STH.LE.0.0) GO TO 500
      XSIGMA=SQRT(XSIGMA/STH)
      YSIGMA=SQRT(YSIGMA/STH)
      RETURN
  500 XAW=99.
      YAW=99.
      XSIGMA=99.
      YSIGMA=99.
      RETURN
      END


     SUBROUTINE BOUT(LEN,$,$)
      COMMON/INDAT/ODAT(510),IEND,NXTSTA,LSTSTA
      WRITE(2) LEN,(ODAT(I),I=1,LEN)
      RETURN 2
      END


      SUBROUTINE CLSTM(J, KK, MM, JTAG, NTPDY, ITABFB, M, NDYDTA, NMM,
     Z KKT, MMT, IRTNS)
**CLOSEST TIME FOR ALTERNATE DATA

      IRTNS=86
      IF(JTAG.EQ.4) GO TO 8
**SECOND CLOSEST TIME, JTAG=2
      IF(ITABFB.EQ.2) GO TO 3
**FORW TRAJECTORIES
    2 IF(MOD(J,2).EQ.0) GO TO 30
      GO TO 10
** BACK TRAJECTORIES
    3 IF(MOD(J,2).EQ.0) GO TO 10
      GO TO 30
**THIRD CLOSEST TIME, JTAG=4(OBS ONLY)
    8 IF(ITABFB.EQ.2) GO TO 2
      GO TO 3
   10 KKT=KK+1
      IF(KKT.LE.NTPDY) GO TO 20
      KKT=1
      MMT=MM+1
      GO TO 60
   20 MMT=MM
      GO TO 60
   30 KKT=KK-1
      IF(KKT.GE.1) GO TO 40
      KKT=NTPDY
      MMT=MM-1
      GO TO 60
   40 MMT=MM
   60 IF (MMT .LT. 1. .OR. MMT .GT. NMM) RETURN
      IF(ITABFB.EQ.2) GO TO 62
      IF (M + MMT -1 .GT. NDYDTA) RETURN
      IRTNS=90
      RETURN
   62 IF (M+MMT-1 .LT. NMM) RETURN
      IRTNS=90
      RETURN
      END


      SUBROUTINE DISO(J, K, M, KK, MM, MXNSTA, NSTA, ITABFB,
     A  ITS, ITPDY, IMM, RADIUS, TSDUR, MBIP, MEIP, SLATT, SLONT, TSLAT1
     A, TSLON1, XAWT, YAWT, XXSIG, YYSIG, KKT, MMT, SJTAG, JTAG, ICNTMN,
     A ICNTMX, XIP, YIP, XTSIP, YTSIP, DXSIGP, DYSIGP, WIP, TSLAT2,
     A TSLON2, ISNAP, WIOROT    , UBART, SIGMAH, ICNTT, SICNTT, SPRED1,
     A SPRED2, ALPHAA, BETAA, TA, R2A, IJKA, IRTNS)
```

```
**DISPLACEMENT CALCULATION USING OBSERVED WINDS
      LOGICAL SJTAG(5),SICNTT
      DIMENSION NSTA(ITPDY,IMM)
      DIMENSION XXSIG(MXNSTA),YYSIG(MXNSTA)
      DIMENSION XAWT(MXNSTA),YAWT(MXNSTA)
      DIMENSION SLATT(MXNSTA),SLONT(MXNSTA)
      INTEGER XIP(ICNTMX),YIP(ICNTMX),XTSIP(ICNTMX),YTSIP(ICNTMX),
     A        WIP(ICNTMX),XTSP,YTSP
      COMMON /STAT/ SLAT(100,4,8), SLON(100,4,8), XAW(100,4,8),
     Z YAW(100,4,8), XSIGMA(100,4,8), YSIGMA(100, 4,8)
      INTEGER DXSIGP(ICNTMX),DYSIGP(ICNTMX)
      DATA PI/3.14159/
      IRTNS=0
      SWXTSI=0.
      SWYTSI=0.
      SDXSIG=0.
      SDYSIG=0.
      SWI=0.
      ICNTT=0
      NEAR=0
      IF(JTAG.EQ.0) GO TO 90
      IF(NSTA(KKT,MMT).EQ.0) RETURN
      NSTADO=NSTA(KKT,MMT)
      DO 80 I=1,NSTADO
      SLATT(I)=SLAT(I,KKT,MMT)
      SLONT(I)=SLON(I,KKT,MMT)
      XAWT(I)=XAW(I,KKT,MMT)
      YAWT(I)=YAW(I,KKT,MMT)
      XXSIG(I)=XSIGMA(I,KKT,MMT)
      YYSIG(I)=YSIGMA(I,KKT,MMT)
   80 CONTINUE
      GO TO 95



   90 IF(NSTA(KK,MM).EQ.0) RETURN
      NSTADO=NSTA(KK,MM)
   95 DO 150 I=1,NSTADO
      IF (JTAG .NE. 0) GO TO 96
        SLATT(I)=55.
          SLONT(I)=55.
          XAWT(I)=66.
          YAWT(I)=66.
          XXSIG(I)=77.
          YYSIG(I)=77.
   96 CALL    ITSIW    ( JTAG, RADIUS, SLAT(I,KK,MM), SLON(I,KK,MM),
     Z SLATT(I), SLONT(I), XAW(I,KK,MM), YAW(I,KK,MM), XSIGMA(I,KK,MM),
     Z YSIGMA(I, KK, MM), XAWT(I), YAWT(I),XXSIG(I), YYSIG(I), TSDUR,
     Z TSLAT1, TSLON1, ITABFB, NEAR, XI, YI, XTSI, YTSI, DXSIGI, DYSIGI,
     Z WI, IJRTNS)
      IF (IJRTNS .EQ. 150) GO TO  150
      ICNTT=ICNTT+1
      XIP(ICNTT)=XI+.5
      YIP(ICNTT)=YI+.5
      XTSIP(ICNTT)=XTSI/3.+.5
      YTSIP(ICNTT)=YTSI/3.+.5
      DXSIGP(ICNTT)=DXSIGI/3.+0.5
      DYSIGP(ICNTT)=DYSIGI/3.+0.5
      WIP(ICNTT)=WI*1000000.
      SWXTSI=SWXTSI+WI*XTSI
      SWYTSI=SWYTSI+WI*YTSI
      SDXSIG=SDXSIG+WI*DXSIGI
      SDYSIG=SDYSIG+WI*DYSIGI
      SWI=SWI+WI
  150 CONTINUE
      IF(ICNTT .LT. ICNTMN .AND. NEAR .NE. 1) RETURN
**NOT SUFFICIENT OBSERVED WINDS
**TRAJECTORY SEGMENT DISPLACEMENT***************************************
      IF (SWI .EQ. 0.) SWI=.0001
      XTS=SWXTSI/SWI
      YTS=SWYTSI/SWI
      XSDX=SDXSIG/SWI
      YSDY=SDYSIG/SWI
      XTSP=XTS/3.+.5
      YTSP=YTS/3.+.5
      TSLAT2=TSLAT1+YTS/60.
      TSLON2=TSLON1-XTS/(60.*COS(TSLAT1*PI/180.))
      UBART=.515*SQRT(XTS*XTS+YTS*YTS)/TSDUR
      UBARTT=UBART/0.515
      SIGMAH=(ABS(XTS)*YSDY+ABS(YTS)*XSDX)/(UBARTT*TSDUR)
      SPRED2=SPRED1+SIGMAH
      CALL XSZ(TSLAT1,TSLON1,TSLAT2,TSLON2,XTS,YTS,SPRED2,ALPHAA,BETAA,
     A      IJKA,R2A,TA,WIOROT)
      SICNTT=SJTAG(JTAG+1)
      IF (M .GE. MBIP .AND. M .LE. MEIP) GO TO 172
      IRTNS=170
      RETURN
  172 IF(ISNAP .EQ. 1) GO TO 175
**PRINT TRAJECTORY SEGMENT DISPLACEMENT AND*****************************
**INDIVIDUAL STATION RELATIVE LOCATIONS AND DISPLACEMENTS***************
```

```
      IF(ISNAP.EQ.1) GO TO 175
      ISNAP=1
      WRITE(6,173)
  173 FORMAT(1H ,'  J  K  M TAG CNT XTS YTS'/
     A        1H ,'                                   XI    YI XTSIYTSI WI',
     A            '              XI    YI XTSIYTSI WI   XI    YI XTSIYTSI WI',
     A            '              XI    YI XTSIYTSI WI')
  175 WRITE(6,180) J,K,M,JTAG,ICNTT,XTSP,YTSP,
     A            (XIP(IP),YIP(IP),XTSIP(IP),YTSIP(IP),WIP(IP),IP=1,ICNTT)
  180 FORMAT(1H ,3I3,4I4/
     A          1H ,25X,4(3X,2I5,3I4)/1H ,25X,4(3X,2I5,3I4)/
     A          1H ,25X,4(3X,2I5,3I4)/1H ,25X,4(3X,2I5,3I4)/
     A          1H ,25X,4(3X,2I5,3I4)/1H ,25X,4(3X,2I5,3I4)/
     A          1H ,25X,4(3X,2I5,3I4)/1H ,25X,4(3X,2I5,3I4))
      IRTNS=170
      RETURN
      END


      SUBROUTINE DTABKO(M, MXNSTA, NTPDY, NMM, NSTA, ITABFB, NDYDTA,
     Z ITPDY, IMM, DTABT, DTABB, DTABL, DTABR, LBAAT, LTAAT, OLAT,
     Z OLON, SID)
C**DATA BLOCK FOR OBSERVED INFORMATION

      DIMENSION NSTA(ITPDY,IMM)
      INTEGER SID(MXNSTA,ITPDY)
      COMMON /STAT/ SLAT(100,4,8), SLON(100,4,8), XAW(100,4,8),
     Z YAW(100,4,8), XSIGMA(100,4,8), YSIGMA(100, 4,8)
      COMMON /DATERD/IDMO,IDYR,IDDY,IDHR,NRSTA,NREC,IH
      DIMENSION SI(100),SLA(100),SLO(100),XA(100),YA(100),XS(100),
     Z    YS(100)
      IF(M.GT.1) GO TO 5
      WRITE(6,4)
    4 FORMAT(1H ,27X,'NUMBER OF    NUMBER     NUMBER OF'/
     B       1H ,27X,'REPORTING      OF      STATIONS IN'/
     C     1H ,27X,' STATIONS   RECORDS    BOUNDARIES')
    5 DO 200 MM=1,NMM
      GO TO (1,2),ITABFB
    1 IF(M.EQ.1) GO TO 8
      IF(M+MM-1.GT.NDYDTA) GO TO 200
      GO TO 3


    2 IF(M+MM-1.LT.NMM) GO TO 200
    3 IF(MM.EQ.NMM) GO TO 8
      DO 10 K = 1, NTPDY
      NSTAT=NSTA(K,MM+1)
      NSTA(K,MM)=NSTAT
      DO 9 I=1,NSTAT
      SLAT(I,K,MM)=SLAT(I,K,MM+1)
      SLON(I,K,MM)=SLON(I,K,MM+1)
      XAW(I,K,MM)=XAW(I,K,MM+1)
      YAW(I,K,MM)=YAW(I,K,MM+1)
      XSIGMA(I,K,MM)=XSIGMA(I,K,MM+1)
      YSIGMA(I,K,MM)=YSIGMA(I,K,MM+1)
    9 CONTINUE
   10 CONTINUE
      GO TO 200
    8 DO 199 K=1,NTPDY
      CALL POSTP(M,MM,K)
      CALL    RDAVO    ( MXNSTA, DTABT, DTABB, DTABL, DTABR, LBAAT, LTAAT,
     Z OLAT,OLON,SI,SLA,SLO,XA,YA,XS,YS,NSTA(K,MM))
      DO 101 I=1,100
      SID(I,K)=SI(I)
      SLAT(I,K,MM)=SLA(I)
      SLON(I,K,MM)=SLO(I)
      XAW(I,K,MM)=XA(I)
      YAW(I,K,MM)=YA(I)
      XSIGMA(I,K,MM)=XS(I)
      YSIGMA(I,K,MM)=YS(I)
  101 CONTINUE
  199 CONTINUE
  200 CONTINUE
      RETURN
      END


      SUBROUTINE INPUT(NTPDY, TSDUR, RADIUS, ICNTMN, ICNTMX, MBIP, MEIP,
     Z MXNO, NO, OID, OLAT, OLON, WIOROT, IHRINP, NLVLA, NTSPDY,
     Z NTS, NMM)
C**INPUT INFORMATION
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```
      DIMENSION OID(MXNO),OLAT(MXNO),OLON(MXNO)
      DIMENSION WIOROT(5)
      COMMON/INPUT1/IBDY,IBMO,IBYR,NDY,TDIR,
     A          POLLAT,IHOUR,IMO,
     A         NDYDUR,NDYDTA,WTYPE,DTABT,DTABB,DTABL,DTABR,
     A     LBAAT,LTAAT,ALATT,ALATB,ALONL
**********************************************************************
**INPUT DATA CARDS*************************** ************************
**CARD 0**
**NUMBER OF ORIGINS
      READ(5,100) NO,NDY
  100 FORMAT(I2,1X,I2)
**CARD 1**
**ORIGIN IDENTIFIED BY LETTERS(OID), LATITUDE(OLAT), LONGITUDE(OLON)
      DO 101 IO=1,NO



      READ(5,1) OID(IO),OLAT(IO),OLON(IO)
    1 FORMAT(A3,1X,F4.1,1X,F6.1)
  101 CONTINUE
      DO 102 IO=1,NO
      READ(5,200) WIOROT(IO)
  200 FORMAT(F10.1)
  102 CONTINUE
**CARD 2**
**DATE COMPUTATIONS BEGIN: DAY(IBDY), MONTH(IBMO), YEAR(IBYR)
**NUMBER OF DAYS COMPUTATIONS DESIRED(NDY)
      READ(5,2) IBDY,IMO,IBYR,IHOUR,IBMO
    2 FORMAT(4(I2,1X),2X,A3)
**CARD 3**
**DIRECTION IN TIME(TDIR), FORWARD(FORW), BACKWARD(BACK)
**DURATION IN DAYS(NDYDUR)
      READ(5,3) TDIR,NDYDUR
    3 FORMAT(A4,1X,I2)
**CARD 4**
**NUMBER OF DAYS OF WIND INPUT DATA(NDYDTA)
      READ(5,4) NDYDTA
    4 FORMAT(I2)
**CARD 5**
**TYPE OF WIND INPUT DATA(WTYPE)
**OBSERVED(OBS), ANALYZED(ANA),OBSERVED AND ANALYZED(O,A)
      READ(5,5) WTYPE
    5 FORMAT(A3)
**CARD 6**
**BOUNDARIES FOR OBSERVED WIND INPUT DATA
**TOP LATITUDE(DTABT), BOTTOM LATITUDE(DTABB),
**LEFT LONGITUDE(DTABL), RIGHT LONGITUDE(DTABR)
      READ(5,6) DTABT,DTABB,DTABL,DTABR
    6 FORMAT(F4.1,1X,F4.1,1X,F6.1,1X,F6.1)
**CARD 8**
**TRANSPORT LAYER BASE(LBAAT), AND TOP(LTAAT) IN METERS
**ABOVE AVERAGE TERRAIN
      READ(5,8) LBAAT,LTAAT
    8 FORMAT(I4,1X,I4)
**CARD 9**
**BOUNDARIES FOR MAPS IN SUBROUTINES:
** LATITUDE OF MAP    TOP BOUNDARY(ALATT)
** LATITUDE OF MAP BOTTOM BOUNDARY(ALATB)
**LONGITUDE OF MAP   LEFT BOUNDARY(ALONL)
**(MAP WIDTH IN LONGITUDINAL DEGREES IS OBTAINED FROM
    SEPARATE TABULATION)
      READ(5,9) ALATT,ALATB,ALONL
    9 FORMAT(F4.1,1X,F4.1,1X,F6.1)
**END INPUT DATA CARDS*************************************** ********
**********************************************************************

**********************************************************************
**INPUT PARAMETERS****************************************************
**NUMBER OF TRAJECTORIES PER DAY
      NTPDY=4
**TRAJECTORY SEGMENT DURATION IN HOURS
      TSDUR=3.
**RADIUS IN NAUTICAL MILES FOR INCLUDING OBSERVED WINDS
**IN DISPLACEMENT CALCULATIONS
      RADIUS=300.
**MINIMUM NUMBER OF STATIONS WITHIN RADIUS
**FOR A DISPLACEMENT CALCULATION
      ICNTMN=2
**MAXIMUM NUMBER OF STATIONS WITHIN RADIUS
**FOR A DISPLACEMENT CALCULATION
      ICNTMX=30
**LATITUDE ABOVE WHICH DISTANCES ARE CALCULATED
   IN A POLAR COORDINATE SYSTEM
      POLLAT=60.
**BEGINNING AND ENDING M IN M=1,NDY LOOP FOR PRINTING
**TRAJECTORY SEGMENT DISPLACEMENTS AND INDIVIDUAL STATION
**RELATIVE LOCATIONS AND DISPLACEMENTS
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```
      MBIP=0
      MEIP=0
**PRINTING INTERVAL IN HOURS
      IHRINP=12
**NUMBER OF ANALYSIS LEVELS
      NLVLA=4
**END INPUT PARAMETERS**********************************************
********************************************************************

**NUMBER OF TRAJECTORY SEGMENTS PER DAY



      NTSPDY=24/TSDUR
**NUMBER OF TRAJECTORY SEGMENTS
      NTS=20
**NUMBER OF DAYS IN DATA BLOCK (DTABK)
      NMM=NDYDUR+1
**PRINT INPUT DATA CARD INFORMATION
      WRITE(6,20)
     1               (OID(IO),OLAT(IO),OLON(IO),IO=1,NO)
      WRITE(6,21) IBDY,IBMO,IBYR,NDY,
     3               TDIR,NDYDUR,
     4               NDYDTA,
     5               WTYPE,
     6               DTABT,DTABB,DTABL,DTABR,
     8               LBAAT,LTAAT
   20 FORMAT(1H1,16X,'INPUT FOR TRAJECTORY COMPUTATIONS'/
     A1H ,'INPUT'/1H ,' DATA'/1H ,' CARD'/
     11H ,4X,41H1 ORIGIN ********************************* ,
     A    A3,'(',F4.1,1X,F6.1,')'/10(46X,A3,'(',F4.1,1X,F6.1,')'/))
   21 FORMAT(
     21H ,4X,41H2 D-TE THAT COMPUTATIONS BEGIN ********** ,I2,1X,A3,1X,I
     H2/
     B1H ,4X,41H  NUMBER OF DAYS COMPUTATIONS DESIRED ** ,I2/
     31H ,4X,41H3 DIRECTION IN TIME ********************** ,A4/
     A1H ,4X,41H  DURATION IN DAYS *********************** ,I2/
     41H ,4X,41H4 NUMBER OF DAYS OF WIND INPUT DATA **** ,I2/
     51H ,4X,41H5 TYPE OF WIND INPUT DATA *************** ,A3/
     61H ,4X,41H6 BOUNDARIES FOR OBSERVED WIND INPUT DATA/
     A1H ,4X,41H  TOP AND BOTTOM LATITUDES ************** ,2X,F4.1,
     A           3X,F4.1/
     B1H ,4X,41H  LEFT AND RIGHT LONGITUDES ************* ,F6.1,1X,F6.1/
     81H ,4X,30H8 TRANSPORT LAYER BASE AND TOP/
     A1H ,4X,41H  IN METERS ABOVE AVERAGE TERRAIN ****** ,I4,1X,I4)
      WRITE(6,25) ALATT,ALATB,ALONL
   25 FORMAT(
     91H ,4X,36H9 BOUNDARIES FOR MAPS IN SUBROUTINES/
     A1H ,4X,41H  TOP LATITUDE ************************** ,2X,F4.1/
     B1H ,4X,41H  BOTTOM LATITUDE *********************** ,2X,F4.1/
     C1H ,4X,41H  LEFT LONGITUDE ************************ ,F6.1)
      WRITE(6,30)
   30 FORMAT(1H1)
      RETURN
      END


      SUBROUTINE ITSIW(JTAG, RADIUS, SLAT, SLON, SLATT, SLONT, XAW, YAW,
     Z XSIGMA, YSIGMA, XAWT, YAWT, XXSIG, YYSIG, TSDUR, TSLAT1, TSLON1,
     Z ITABFB, NEAR, X, Y, XTS, YTS, DXSIG, DYSIG, W, IJRTNS)

**CONTRIBUTION TO A TRAJECTORY SEGMENT
**FROM AN INDIVIDUAL STATION AND ITS WEIGHT


      DATA PI/3.14159/
      IJRTNS=150
      IF(JTAG.EQ.0) GO TO 3
      SLATSH=SLATT
      SLONSH=SLONT
      GO TO 5
    3 SLATSH=SLAT
      SLONSH=SLON
    5 X=(TSLON1-SLONSH)*60.*COS(SLATSH*PI/180.)
      Y=(SLATSH-TSLAT1)*60.
      D=SQRT(X*X+Y*Y)
      IF (D .GT. RADIUS) RETURN
      IF(JTAG.EQ.0) GO TO 10
      IF (XAWT .EQ. 99.) RETURN
      GO TO 12
   10 IF (XAW .EQ. 99.) RETURN
   12 IF(D.LE.RADIUS/2.) NEAR=1
      IF(JTAG.EQ.0) GO TO 20
      XAWSH=XAWT
      YAWSH=YAWT
      XXSIGS=XXSIG
      YYSIGS=YYSIG
      GO TO 18
   20 XAWSH=XAW
```

```
      YAWSH=YAW
      XXSIGS=XSIGMA
      YYSIGS=YSIGMA
   18 GO TO (21,22),ITABFB
   21 XTS=1.94*XAWSH*TSDUR


      YTS=1.94*YAWSH*TSDUR
      DXSIG=1.94*XXSIGS*TSDUR
      DYSIG=1.94*YYSIGS*TSDUR
      GO TO 23
   22 XTS=-1.94*XAWSH*TSDUR
      YTS=-1.94*YAWSH*TSDUR
      DXSIG=-1.94*XXSIGS*TSDUR
      DYSIG=-1.94*YYSIGS*TSDUR
   23 CONTINUE
      DTS=SQRT(XTS*XTS+YTS*YTS)
      XW=-X+XTS/2.
      YW= Y-YTS/2.
      DWSQ=XW*XW+YW*YW
      IF(DWSQ.EQ.0.) DWSQ=.0001
      DISTW=1./DWSQ
      ALINW=1.
      IF(D .NE. 0. .AND. DTS .NE. 0.) ALINW=1.-.5*ABS((YTS*X-XTS*Y)/
     Z  (DTS*D+ .0001))
      W=DISTW*ALINW
      IJRTNS=0
      RETURN
      END


      WDIR=HDS(2,LVL)
      WSPD=HDS(3,LVL)
      XW(LVL)=-WSPD*SIN(WDIR*PI/180.)
      YW(LVL)=-WSPD*COS(WDIR*PI/180.)
   50 CONTINUE
      IF(LBAAT.NE.0) GO TO 60
      XI=(OLON-SLON(I))*60.*COS(SLAT(I)*PI/180.)
      YI=(SLAT(I)-OLAT)*60.
      DI=SQRT(XI*XI+YI*YI)
   60 CALL   AWIND   ( SHT, SATH, DI, LBAAT, LTAAT, WHT, XW, YW, NLVL,
     Z XAW(I), YAW(I), XSIGMA(I), YSIGMA(I))
  100 CONTINUE
  110 WRITE(6,120) NSTA
  120 FORMAT(1H+,54X,I3)
      RETURN
      END


      SUBROUTINE RDDATA(I)
      COMMON /INDAT/ODAT(510),IEND,NXTSTA,LSTSTA
      ISW=0
  100 CALL TAPEX ('WINDDATA7,1,1,IOST,510,ODAT,LEN)
       IF(IOST.EQ.0.OR.IOST.EQ.4) GOTO 115
        IF(IOST.EQ.1) GOTO 116
        GOTO 117
  116 IF(ISW.NE.0) GO TO 98
      ISW=10
      GO TO 100
  117 WRITE(6,2002)
 2002 FORMAT(' FR RDDATA, I-0,02')
  115 ISW=0
       IF(LEN.EQ.510) GO TO 150
      IF(LEN.EQ.510) GO TO 150
      WRITE(6,2003) LEN
 2003 FORMAT(' FR RDDATA, BAD LEN'I10)
  150 I=I-170
      NXTSTA=NXTSTA-170
      GO TO 99
   98 IEND=10
   99 RETURN
      END


      SUBROUTINE RDDATE
  FOR CSU TAPES
      COMMON /DATERD/IDMO,IDYR,IDDY,IDHR,NRSTA,NREC,IM
      COMMON /INDAT/ODAT(510),IEND,NXTSTA,LSTSTA
      DATA IZER/0/
      ISW=0
       CALL TAPEX('WINDDATA',1,1,IOST,510,ODAT,LEN)
       IF(IOST.EQ.0.OR.IOST.EQ.4) GO TO 115
      IF(IOST.EQ.1) GO TO 116
        GO TO 117
 116 IF(ISW.NE.0) GO TO 98
     ISW=10
     GO TO 100
 117 WRITE(6,2002)
2002 FORMAT(' FR RDDATE, I-0',02)
 115 ISW=0
     IF(LEN.GT.20) GO TO 100
     IDMO=ODAT(1)
     IDYR=ODAT(2)
     IDDY=ODAT(3)
     IDHR=ODAT(4)
     NRSTA=ODAT(5)
     NREC=ODAT(6)
     IM=ODAT(7)
     NXTSTA=171
     LSTSTA=171
     GO TO 99
  98 IEND=10
  99 RETURN
     END



     SUBROUTINE RDSTHD
 FOR CSU TAPES
     COMMON /STHDRD/ISTNO,ALAT,ALON,ISTH,ISATH,NLVL
     COMMON /INDAT/ODAT(510),IEND,NXTSTA,LSTSTA
     DIMENSION DAT(3,170)
     EQUIVALENCE (ODAT(1),DAT(1))
     DATA IDUM/0/
     IF(NXTSTA.GT.170) CALL RDDATA(IDUM)
     ISTNO=DAT(1,NXTSTA)
     ALAT=DAT(2,NXTSTA)
     ALON=DAT(3,NXTSTA)
     I=NXTSTA+1


     SUBROUTINE KKMM(J, K, M, KK, MM, NMM, NDYDTA, NTSPDY,ITABFB,IRTNS)

**DETERMINE PROPER TRAJECTORY SEGMENT
**TIME OF DAY(KK) AND DAY(MM) IN DATA BLOCK DTABK

     IRTNS=0
     KKS=KK
     IF (ITABFB .EQ. 2) GO TO 52
     KKT=1.+.5*FLOAT(J)+K-1
     KK=MOD(KKT-1,4)+1
     IF(KK.LT.KKS) MM=MM+1
     IF(M+MM-1.LE.NDYDTA) IRTNS=90
     RETURN
  52 KKT=5.5-.5*FLOAT(MOD(J-1,NTSPDY)+1)+K-1
     KK=MOD(KKT-1,4)+1
     IF(KK.GT.KKS) MM=MM-1
     IF(M+MM-1.GE.NMM) IRTNS=90
     RETURN
     END


     SUBROUTINE POSTP(M,MM,K)

**POSITION TAPES FOR STARTING RUN AT DESIGNATED BEGINNING TIME

     COMMON/INPUT1/IBDY,IBMO,IBYR,NDY,TDIR,
    A          POLLAT,IHOUR,IMO,
    A         NDYDUR,NDYDTA,WTYPE,DTABT,DTABB,DTABL,DTABR,
    A     LBAAT,LTAAT,ALATT,ALATB,ALONL
     COMMON /DATERD/IDMO,IDYR,IDDY,IDHR,NRSTA,NREC,IM
     COMMON /INDAT/ODAT(510),IEND,NXTSTA,LSTSTA
     IEND=0
   5 CALL RDDATE
     IF(IEND.NE.0) STOP 333
     IF(M.NE.1.OR.MM.NE.1.OR.K.NE.1) GO TO 100
     IF(IM.NE.IMO) GO TO 5
     IF(IDDY.NE.IBDY) GO TO 5
     IF(IDHR.NE.IHOUR) GO TO 5
 100 RETURN
     END


     SUBROUTINE RDAVO(MXNSTA, DTABT, DTABB, DTABL, DTABR, LBAAT, LTAAT,
    Z OLAT, OLON, SID, SLAT, SLON, XAW, YAW, XSIGMA, YSIGMA, NSTA)

**READ AND AVERAGE OBSERVED WINDS
```

```
      INTEGER SID(MXNSTA),SIDT,SHT,SATH
      INTEGER WHT(50)
      DIMENSION SLAT(MXNSTA),SLON(MXNSTA)
      DIMENSION XAW(MXNSTA),YAW(MXNSTA)
      DIMENSION XSIGMA(MXNSTA),YSIGMA(MXNSTA)
      DIMENSION XW(50),YW(50)
       DIMENSION MTH(12)
      COMMON /DATERD/IDMO,IDYR,IDDY,IDHR,NRSTA,NREC,IM
      COMMON /STHDRD/ISTNO,ALAT,ALON,ISTH,ISATH,NLVL
      COMMON /INDAT/ODAT(510),IEND,NXTSTA,LSTSTA
      COMMON /WINDRD/HDS(3,50)
      DATA PI/3.14159/
       DATA MTH /'JAN','FEB','MAR','APR','MAY','JUN','JUL','AUG','SEP',
     A  'OCT','NOV','DEC'/
      WRITE(6,15) IDYR,IDMO,IDDY,IDHR,NRSTA,NREC
   15 FORMAT(1H ,9X,I4,1X,A3,1X,I2,'-',I2,'Z',6X,I4,6X,I5)
      NSTA=0
      ISOVER=MXNSTA
      IF(NRSTA.EQ.0) GO TO 110
      DO 100 IR=1,NRSTA
      CALL RDSTHD
      SIDT=ISTNO
      SLATT=ALAT
      SLONT=ALON
      SHT=ISTH
      SATH=ISATH
      IF(SLATT.LE.DTART.AND.SLATT.GE.DTABB.AND.
     A    SLONT.LE.DTABL.AND.SLONT.GE.DTABR) GO TO 40
      CALL RDWIND
      GO TO 100
   40 NSTA=NSTA+1
      IF(NSTA.LE.MXNSTA) GO TO 44
      ISOVER=ISOVER+1
      WRITE(6,42) ISOVER,MXNSTA,SIDT,SLATT,SLONT
   42 FORMAT(1H ,70X,'ISTAOVER=',I3,2X,'MXNSTA=',I3,
     A       3X,I5,'(',F4.1,1X,F6.1,')')
      NSTA=MXNSTA
   44 CONTINUE
      I=NSTA
      SID(I)=SIDT
      SLAT(I)=SLATT
      SLON(I)=SLONT
      CALL RDWIND
      DO 50 LVL=1,NLVL
      WHT(LVL)=HDS(I,LVL)
      IF(I.GT.170) CALL RDDATA(I)
      ISTH=DAT(1,I)
      ISATH=DAT(2,I)
      NLVL=DAT(3,I)
      LSTSTA=NXTSTA
      NXTSTA=NXTSTA+(NLVL+2)
      RETURN
      END


      SUBROUTINE RDWIND
  FOR CSU TAPES
      COMMON /STHDRD/ISTNO,ALAT,ALON,IST8,ISATH,NLVL
      COMMON /INDAT/ODAT(510),IEND,NXTSTA,LSTSTA
      COMMON /WINDRD/HDS(3,50)
      DIMENSION DAT(3,170)
      EQUIVALENCE(ODAT(1),DAT(1))
      IST=LSTSTA+2
      IF(IST.GT.170) CALL RDDATA(IST)
      IEN=IST+(NLVL-1)
      JEN=IEN
      K=0
      IF(IEN.LT.171) GO TO 150
      JEN=170
  150 DO 10 I = IST, JEN
      K=K+1
      HDS(1,K)=DAT(1,I)
      HDS(2,K)=DAT(2,I)
      HDS(3,K)=DAT(3,I)
   10 CONTINUE
      IF(JEN.EQ.IEN) GO TO 99
      CALL RDDATA(IEN)
      DO 20 I=1,IEN
      K=K+1
      HDS(1,K)=DAT(1,I)
      HDS(2,K)=DAT(2,I)
      HDS(3,K)=DAT(3,I)
   20 CONTINUE
   99 RETURN
      END
      SUBROUTINE XSZ(TSLAT1,TSLON1,TSLAT2,TSLON2,XTS,YTS,SPRED2,ALPHAA
     A ,BETAA,IJKA,R2A,TA,WIOROT)
C----DETERMINES THE DISTANCE,R2,AND THE ANGLES,ALPHAA,BETWEEN TRAJECTORY
C     END POIMTS, AND THE DISTANCE TA, AND THE ANGLE,BETAA, BETWEEN TRAJECTORY
C    ENDPOINT ANU SPREAD END POINT----------------------------------
      PI=3.14159
      WORO=WIOROT/1852.0
      R2=XTS*XTS+YTS*YTS
      R2A=SQRT(R2)
      S2=(WORO/2.+SPRED2)*(WORO/2.+SPRED2)
      T2=R2+S2
      TA=SQRT(T2)
      IF(R2.EQ.0.) GO TO 101
      IF(XTS.EQ.0.) GO TO 1
      Z1=ABS(YTS/XTS)
      ALPHAA=ATAN(Z1)
      GO TO 5
    1 ALPHAA=.5*PI
    5 IF(R2A.EQ.0.) GO TO 6
      Z2=SQRT(S2/R2)
      BETAA=ATAN(Z2)
      GO TO 7
    6 BETAA=0.
    7 CONTINUE
      IF(TSLAT2.GE.TSLAT1.AND.TSLON2.LE.TSLON1) GO TO 10
      IF(TSLAT2.GE.TSLAT1.AND.TSLON2.GT.TSLON1) GO TO 20
      IF(TSLAT2.LT.TSLAT1.AND.TSLON2.GT.TSLON1) GO TO 30
      IF(TSLAT2.LT.TSLAT1.AND.TSLON2.LE.TSLON1) GO TO 40
   10 IJKA=1
      ALPHAA=ALPHAA
      RETURN
   20 IJKA=2
      ALPHAA=PI-ALPHAA
      RETURN
   30 IJKA=3
      ALPHAA=PI+ALPHAA
      RETURN
   40 IJKA=4
      ALPHAA=2.*PI-ALPHAA
      RETURN
  101 ALPHAA=0.
      BETAA=0.
      IJKA=0
      RETURN
      END
```

Program of Concentration Calculation (Model A)

```
      PROGRAM TRAJET
C THIS PROGRAM WILL READ IN DATA COMPUTED FROM THE PREVEOUS PROGRAM
C TO  COMPUTE THE RESULTANT CONCENTRATIONS ETC.
      COMMON /OUTP1/ TSLAT(20,4,8), TSLON(20,4,8), UBAR(20,4,8)
     Z , SPREAD(20,4,8)
      COMMON /OUTP2/ ALPHA(20,4,8), BETA(20,4,8), IJK(20,4,8)
     Z , T(20,4,8), R2(20,4,8)
      COMMON/GRID/BLAT(31),BLON(31),CONG(31,31),SCONG(31,31),XXJ(31,31),
     Z    SXXJ(31,31),DXXJ(31,31),DSXXJ(31,31)
      INTEGER ICNT(20,4,8)
      LOGICAL SICNT(20,4,8)
      INTEGER TSLAT, TSLON
      DIMENSION OID(5),OLAT(5),OLON(5)
      DO 20 I = 1, 5
          READ(14, 10) OID(I), OLAT(I), OLON(I)
   10 FORMAT (A3, F4.1, F6.1)
   20 CONTINUE
       READ(14, 30) NO, NDY, NTS, NTPDY, LTAAT
   30 FORMAT(5I10)
       READ(14, 40 ) TSDUR, ALATT, ALONL
   40 FORMAT(3F15.5)
      DO 500 IO=1,NO
      IF(NO.EQ.1) GO TO 450
      WRITE(6,416) OID(IO),OLAT(IO),OLON(IO)
  416 FORMAT(1H1,A3,'(',F4.1,1X,F6.1,')')
      KUNIT=20+IO
      DO 425 M=1,NDY
         DO 422 K = 1, NTPDY
            DO 420 J = 1, NTS
               READ (KUNIT) TSLAT(J,K,M), TSLON(J,K,M), UBAR(J,K,M),
     Z SPREAD(J,K,M), ALPHA(J,K,M), BETA(J,K,M ), T(J,K,M), R2(J,K,M),
     Z IJK(J,K,M), ICNT(J,K,M), SICNT(J,K,M)
```

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```
  420         CONTINUE
  422      CONTINUE
  425 CONTINUE
  450 CONTINUE
      CALL CONCAL (IO,NO,OLAT,OLON,                            NTS
     A ,NTPDY,NDY,TSDUR,ALATT,ALONL,LTAAT)
  500 CONTINUE
      STOP
      END


      SUBROUTINE CONCAL(IO,NO,OLAT,OLON,
     ANTS,NTPDY,NDY,TSDUR,ALATT,ALONL,LTAAT)
------CALCULATE THE CONCENTRATIONS ON GRID POINTS-------------------
      COMMON /OUTP1/ TSLAT(20,4,8), TSLON(20,4,8), UBAR(20,4,8)
     Z , SPREAD(20,4,8)
      COMMON /OUTP2/ ALPHA(20,4,8), BETA(20,4,8), IJK(20,4,8)
     Z , T(20,4,8), R2(20,4,8)
      COMMON/GRID/BLAT(31),BLON(31),CONG(31,31),SCONG(31,31),XXJ(31,31),
     Z    SXXJ(31,31),DXXJ(31,31),DSXXJ(31,31)
      DIMENSION VG1(20,4),VG2(20,4),CONVR(20,4),H(20,4),RAMDA1(20,4),
     Z RAMDA2(20,4)
      INTEGER TSLAT,TSLON
      DIMENSION WOR(20,4,8), CONC(20,4,8),SCONC(20,4,8)
      DIMENSION GAMMA(31,31),C(31,31)
      DIMENSION ORCON(5),SORCON(5),WIORO(5)
      DIMENSION OLAT( 5),OLON( 5)
      DIMENSION INDEX(31,31),INDEX2(31,31)
      PI=3.14159
      DO 4000 K=1,NTPDY
      DO 3000 J=1,NTS
      CALL REMOVE(K,J,VGA,VGB,TRAR,HGT,RAMAA,RAMBB,LTAAT)
      VG1(J,K)=VGA
      VG2(J,K)=VGB
      CONVR(J,K)=TRAR
      H(J,K)=HGT
      RAMDA1(J,K)=RAMAA
      RAMDA2(J,K)=RAMBB
 3000 CONTINUE
 4000 CONTINUE
      READ(5,77) ORCON(IO),SORCON(IO),WIORO(IO)
   77 FORMAT(3F10.1)
      WORO=WIORO(IO)
      DO 87 M = 1, 8
         DO 86 K = 1, 4
            DO 85 J = 1, 20
               WOR(J, K, M)=0.
               CONC(J, K, M)=0.
               SCONC(J, K, M)=0.
   85       CONTINUE
   86    CONTINUE
   87 CONTINUE
      IF(IO.NE.1) GO TO 101
      DO 100 II=1,31
      DO 99 JJ = 1, 31
      III=II-1
      JJK=JJ-1
      BLAT(II)=ALATT-0.5*III
      BLON(JJ)=ALONL-0.5*JJK
      CONG(II,JJ)=0.0
      XXJ(II,JJ)=0.0
      SCONG(II,JJ)=0.0
      SXXJ(II,JJ)=0.0
      DXXJ(II,JJ)=0.0
      DSXXJ(II,JJ)=0.0
   99 CONTINUE
  100 CONTINUE
  101 CONTINUE
      DO 800 M=1,NDY
      DO 700 K=1,NTPDY
      DO 600 J=1,NTS
      REMV1=VG1(J,K)+RAMDA1(J,K)*H(J,K)+CONVR(J,K)*H(J,K)
      REMV2=VG2(J,K)+RAMDA2(J,K)*H(J,K)
      DREMV=REMV1-REMV2
      VG1H=VG1(J,K)/H(J,K)
      VG2H=VG2(J,K)/H(J,K)
      DA=EXP(-VG1H*TSDUR*3600.)
      DB=EXP(-VG2H*TSDUR*3600.)
      DC=EXP(DREMVH*TSDUR*3600.0)
      DP1=EXP(-RAMDA1(J,K)*TSDUR*3600.)
      DP2=EXP(-RAMDA2(J,K)*TSDUR*3600.)
      DCON=EXP(-CONVR(J,K)*TSDUR*3600.)
      SWIDTH=WORO+2.*1852.*SPREAD(J,K,M)*60.
      IF(J.NE.1) GO TO 601
      WOR(J,K,M)=WORO
      CONC(J,K,M)=((ORCON(IO)*WOR(J,K,M))/SWIDTH)*DA*DCON*DP1
      SCONC(J,K,M)=  (SORCON(IO)*WOR(J,K,M)/SWIDTH)*DB*DP2
     A    +(1.5*CONVR(J,K)*H(J,K)/DREMV)*CONC(J,K,M)*DC
      GO TO 600
  601 WOR(J,K,M)=WORO+2.*60.*1852.*SPREAD(J-1,K,M)
```

```
      CONC(J,K,M)=((CONC(J-1,K,M)*WOR(J,K,M))/SWIDTH)*DA*DCON*DP1
      SCONC(J,K,M)=((SCONC(J-1,K,M)*WOR(J,K,M))/SWIDTH)*DB*DP2
     A +(1.5*CONVR(J,K)*H(J,K)/DREMV)
     A     *CONC(J,K,M)*DC
  600 CONTINUE
      DO 650 J=1,NTS

      WRITE(6,651) ALPHA(J,K,M),BETA(J,K,M),IJK(J,K,M),T(J,K,M)
     A,R2(J,K,M),SPREAD(J,K,M),UBAR(J,K,M),TSLAT(J,K,M),TSLON(J,K,M)
  651 FORMAT(2F10.3,I5,4F10.3,2I10)
      IF ( J .EQ. 1) GO TO 599
      IF (TSLAT(J, K, M)/10. .GT. BLAT(1) .AND.
     Z    TSLAT(J-1, K, M)/10. .GE. BLAT(1) .OR.
     Z    TSLAT(J, K, M)/10. .LT. BLAT(31) .AND.
     Z    TSLAT(J-1, K, M)/10. .LE. BLAT(31)) GO TO 700
      IF (TSLON(J, K, M)/10. .GT. BLON(1) .AND.
     Z    TSLON(J-1, K, M)/10. .GE. BLON(1) .OR.
     Z    TSLON(J, K, M)/10. .LT. BLON(31) .AND.
     Z    TSLON(J-1, K, M)/10. .LE. BLON(31)) GO TO 700
  599 CONTINUE
      DO 10 II=1,31
      DO 9 JJ = 1, 31
      IF(J.EQ.1) GO TO 50
      TTLAT=TSLAT(J-1,K,M)/10.
      TTLON=TSLON(J-1,K,M)/10.
      GO TO 51
   50 TTLAT=OLAT(IO)
      TTLON=OLON(IO)
   51 CONTINUE
      GX=(TTLON-BLON(JJ))*60.*COS(TTLAT*PI/180.)
      GY=(BLAT(II)-TTLAT)*60.
      IF(BLON(JJ).EQ.TTLON) GO TO 5
      IF(BLAT(II).EQ.TTLAT) GO TO 6
      RATIO=ABS(GY/GX)
      GAMMA(II,JJ)=ATAN(RATIO)
      IF(BLAT(II).GE.TTLAT.AND.BLON(JJ).LE.TTLON) GO TO 21
      IF(BLAT(II).GE.TTLAT.AND.BLON(JJ).GT.TTLON) GO TO 22
      IF(BLAT(II).LT.TTLAT.AND.BLON(JJ).GT.TTLON) GO TO 23
      IF(BLAT(II).LT.TTLAT.AND.BLON(JJ).LE.TTLON) GO TO 24
   21 GAMMA(II,JJ)=GAMMA(II,JJ)
      GO TO 30
   22 GAMMA(II,JJ)=PI-GAMMA(II,JJ)
      GO TO 30
   23 GAMMA(II,JJ)=PI+GAMMA(II,JJ)
      GO TO 30
   24 GAMMA(II,JJ)=2.*PI-GAMMA(II,JJ)
      GO TO 30
    5 IF(BLAT(II).GE.TTLAT) GO TO 4
      GAMMA(II,JJ)=1.5*PI
      GO TO 30
    4 GAMMA(II,JJ)=0.5*PI
      GO TO 30
    6 IF(BLON(JJ).LE.TTLON) GO TO 7
      GAMMA(II,JJ)=PI
      GO TO 30
    7 GAMMA(II,JJ)=0.
   30 C(II,JJ)=SQRT(GX*GX+GY*GY)
    9 CONTINUE
   10 CONTINUE
      DELTA1=ALPHA(J,K,M)+0.5*PI
      DELTA2=ALPHA(J,K,M)+1.5*PI
      PHAI1=ALPHA(J,K,M)+BETA(J,K,M)
      PHAI2=ALPHA(J,K,M)-BETA(J,K,M)
      DO 222 II=1,31
      DO 221 JJ = 1, 31
      INDEX(II,JJ)=0
      INDEX2(II,JJ)=0
  221 CONTINUE
  222 CONTINUE
      DO 250 II=1,31
      DO 248 JJ = 1, 31
      IF(J.EQ.1.AND.BLAT(II).EQ.OLAT(IO).AND.BLON(JJ).EQ.OLON(IO))
     A        GO TO 350
      IF(J.EQ.1.AND.C(II,JJ).LE.WORO/(2.*1852.) .AND.GAMMA(II,JJ).EQ.
     A      DELTA1.OR.GAMMA(II,JJ).EQ.DELTA2) GO TO 350
      EE = T(J, K, M)* T(J, K, M) - R2(J, K, M)*R2(J, K, M)
      E=SQRT(EE)
      F=R2(J, K, M)+E
      IF(C(II, JJ) .GT. F) GO TO 150
      IF(IJK(J,K,M).EQ.1) GO TO 110
      IF(IJK(J,K,M).EQ.2) GO TO 120
      IF(IJK(J,K,M).EQ.3) GO TO 120
      IF(IJK(J,K,M).EQ.4) GO TO 130
      IF(IJK(J,K,M).EQ.0) GO TO 140
  110 IF(BETA(J,K,M).LT.ALPHA(J,K,M)) GO TO 111
      IF(GAMMA(II,JJ).GE.ALPHA(J,K,M).AND.GAMMA(II,JJ).LE.PHAI1.OR.
     A    GAMMA(II,JJ).GE.(2.*PI+PHAI2).AND.GAMMA(II,JJ).LE.2.*PI.OR.
     A    GAMMA(II,JJ).GT.0. .AND.GAMMA(II,JJ).LT.ALPHA(J,K,M))
     A    GO TO 112
      GO TO 113
  112 DI=R2(J,K,M)/COS(ALPHA(J,K,M)-GAMMA(II,JJ))
```

```
     A    +(1.5*CONVR(J,K)*H(J,K)/DREMV)*CONC(J,K,M)*D6
      INDEX(II,JJ)=2
      GO TO 249
  350 CONG(II,JJ)=ORCON(IO)
      SCONG(II,JJ)=SORCON(IO)
      INDEX(II,JJ)=2
      GO TO 249
  162 CONG(II,JJ)=CONC(J,K,M)
      SCONG(II,JJ)=SCONC(J,K,M)
      INDEX(II,JJ)=2
      GO TO 249
  140 CONG(II,JJ)=0.
      SCONG(II,JJ)=0.0
      INDEX(II,JJ)=1
  249 IF(INDEX2(II,JJ).EQ.2.AND.INDEX(II,JJ).EQ.2) GO TO 251
      GO TO 252
  251 CONG(II,JJ)=0.0
      SCONG(II,JJ)=0.0
  252 XXJ(II,JJ)=XXJ(II,JJ)+CONG(II,JJ)
      SXXJ(II,JJ)=SXXJ(II,JJ)+SCONG(II,JJ)
      DCONG=CONG(II,JJ)*(VG1(J,K)+RAMDA1(J,K))*H(J,K)*3.6*6.0
      DSCONG=SCONG(II,JJ)*(VG2(J,K)+RAMDA2(J,K))*H(J,K)*3.6*6.0
      DXXJ(II,JJ)=DXXJ(II,JJ)+DCONG
      DSXXJ(II,JJ)=DSXXJ(II,JJ)+DSCONG
      INDEX2(II,JJ)=INDEX(II,JJ)
  248 CONTINUE
  250 CONTINUE
      DO 661 II=1,31
      DO 660 JJ = 1, 31
      CONG(II,JJ)=0.0
      SCONG(II,JJ)=0.0
      GAMMA(II,JJ)=0.0
      C(II,JJ)=0.0
  660 CONTINUE
  661 CONTINUE
  650 CONTINUE
      IF(IO.NE.1) GO TO 700
CCCCCCC    JJJ = 4 TIMES THE NUMBER OF DAYS CONSIDERED

      JJJ=28
  700 CONTINUE
  800 CONTINUE
      DO 802 II=1,31
      DO 801 JJ = 1, 31
      XXJ(II,JJ)=XXJ(II,JJ)/FLOAT(JJJ)
      SXXJ(II,JJ)=SXXJ(II,JJ)/FLOAT(JJJ)
  801 CONTINUE
  802 CONTINUE
      WRITE(6,914)
  914 FORMAT(1H1,8X,' CONCENTRATION OF SO2 '////)
      WRITE(6,915) (BLON(JJ),JJ=1,16)
  915 FORMAT(8X,16F8.1/////)
      DO 903 II=1,31
      WRITE(6,904) BLAT(II),(XXJ(II,JJ),JJ=1,16)
  904 FORMAT(F8.1,16E8.2////)
  903 CONTINUE
      WRITE(6,925) (BLON(JJ),JJ=17,31)
  925 FORMAT(1H1,8X,15F8.1/////)
      DO 913 II=1,31
      WRITE(6,941) BLAT(II),(XXJ(II,JJ),JJ=17,31)
  941 FORMAT(F8.1,15E8.2////)
  913 CONTINUE
      WRITE(6,950)
  950 FORMAT(1H1,8X,' CONCENTRATION OF SO4 '////)
      WRITE(6,915) (BLON(JJ),JJ=1,16)
      DO 951 II=1,31
      WRITE(6,904) BLAT(II),(SXXJ(II,JJ),JJ=1,16)
  951 CONTINUE
      WRITE(6,925) (BLON(JJ),JJ=17,31)
      DO 952 II=1,31
      WRITE(6,941) BLAT(II),(SXXJ(II,JJ),JJ=17,31)
  952 CONTINUE
      WRITE(6,953)
  953 FORMAT(1H1,8X,'DEPOSITION OF SO2(KG/KM2)'////)
      WRITE(6,915) (BLON(JJ),JJ=1,16)
      DO 954 II=1,31


      WRITE(6,904) BLAT(II),(DXXJ(II,JJ),JJ=1,16)
  954 CONTINUE
      WRITE(6,925) (BLON(JJ),JJ=17,31)
      DO 955 II=1,31
      WRITE(6,941) BLAT(II),(DXXJ(II,JJ),JJ=17,31)
  955 CONTINUE
      WRITE(6,956)
  956 FORMAT(1H1,8X,'DEPOSITION OF SO4(KG/KM2)'////)
      WRITE(6,915) (BLON(JJ),JJ=1,16)
      DO 957 II=1,31
      WRITE(6,904) BLAT(II),(DSXXJ(II,JJ),JJ=1,16)
  957 CONTINUE
```

```
      WRITE(6,925) ( BLON(JJ),JJ=17,31)
      DO 958 II=1,31
      WRITE(6,941) BLAT(II),(DSXXJ(II,JJ),JJ=17,31)
  958 CONTINUE
      DO 920 II=1,31
      DO 919 JJ = 1, 31
      XXJ(II,JJ)=XXJ(II,JJ)*FLOAT(JJJ)
      SXXJ(II,JJ)=SXXJ(II,JJ)*FLOAT(JJJ)
  919 CONTINUE
  920 CONTINUE
      RETURN
      END


      SUBROUTINE REMOVE(K,J,VGA,VGB,TRAR,HGT,RAMAA,RAMBB,LTAAT)
      IF(K.EQ.1) GO TO 110
      IF(K.EQ.2) GO TO 120
      IF(K.EQ.3) GO TO 130
      IF(K.EQ.4) GO TO 140
  110 IF(J.LE.4) GO TO 111
      IF(J.LE.8) GO TO 112
      IF(J.LE.12) GO TO 111
      IF(J.LE.16) GO TO 112
      GO TO 111
  120 IF(J.LE.2) GO TO 111
      IF(J.LE.6) GO TO 112
      IF(J.LE.10) GO TO 111
      IF(J.LE.14) GO TO 112
      IF(J.LE.18) GO TO 111
      GO TO 112
  130 IF(J.LE.4) GO TO 112
      IF(J.LE.8) GO TO 111
      IF(J.LE.12) GO TO 112
      IF(J.LE.16) GO TO 111
      GO TO 112
  140 IF(J.LE.2) GO TO 112
      IF(J.LE.6) GO TO 111
      IF(J.LE.10) GO TO 112
      IF(J.LE.14) GO TO 111
      IF(J.LE.18) GO TO 112
      GO TO 111
  111 VGA=0.01
      VGB=0.001
      TRAR=3.0E-6
      HGT=FLOAT(LTAAT)
      RAMAA=0.0
      RAMBB=0.0
      RETURN
  112 VGA=0.02
      VGB=0.002
      TRAR=6.0E-6
      HGT=FLOAT(LTAAT)
      RAMAA=0.0
      RAMBB=0.0
      RETURN
      END
```

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APPENDIX - B

FORTRAN LISTING OF MODEL B

Trajectory Calculation Program (Model B)

```
      PROGRAM TRAJET
     1(OUTPUT,DATA1,TAPE5=DATA1,TAPE6=OUTPUT,TAPE1=1002B,TAPE2,
     2 TAPE21=1002B,TAPE22=1002B,TAPE23=1002B,TAPE24=1002B,
     3 TAPE25=1002B,TAPE26=1002B,TAPE27=1002B,TAPE28=1002B,
     4 TAPE29=1002B,TAPE30=1002B,TAPE31=1002B,TAPE32=1002B,TAPE33=1002B,
     5 TAPE34=1002B,TAPE35=1002B,TAPE36=1002B,TAPE37=1002B,TAPE38=1002B,
     6 TAPE39=1002B,TAPE40=1002B,TAPE14=1002B)
          DIMENSION ERSO2(5),ERSUL(5)
      DIMENSION OID(5),OLAT(5),OLON(5),WIOROT(5)
      COMMON/STAT/SLAT ( 80,2,5), SLON (80,2,5),XAW ( 80,2,5),
     Z YAW (80,2,5),XSIGMA(80,2,5),YSIGMA(80,2,5)
      COMMON/STAT2/SLAT2(80,2,5), SLON2(80,2,5),XAW2( 80,2,5),
     Z YAW2(80,2,5),XSIGM2(80,2,5),YSIGM2(80,2,5)
      COMMON/STAT3/SLAT3(80,2,5), SLON3(80,2,5),XAW3( 80,2,5),
     Z YAW3(80,2,5),XSIGM3(80,2,5),YSIGM3(80,2,5)
C**FORWARD AND BACKWARD TRAJECTORY MODEL
C**USING OBSERVED AND ANALYZED INPUT WINDS
C
      LOGICAL SICNT1,SICNT2, SICNT3, SICNT4,SICNT
C**FOR OBSERVED INPUT WINDS ONLY*************************************
      DIMENSION SLATT(80),SLONT(80),XAWT(80),YAWT(80)
      DIMENSION NSTA(2,5),NSTA2(2,5),NSTA3(2,5)
      DIMENSION XXSIG(80),YYSIG(80)
      INTEGER SID(80,2)
      INTEGER SID2(80,2),SID3(80,2)
      INTEGER TSLAT,TSLON
      INTEGER TTLAT1,TTLON1,TTLAT2,TTLON2,TTLAT3,TTLON3,TTLAT4,TTLON4
C**SEE DATA MXNSTA
C*******************************************************************
C*******************************************************************
      LOGICAL SJTAG(5),SICNTT
      INTEGER XIP(30),YIP(30),XTSIP(30),YTSIP(30),WIP(30)
      INTEGER DXSIGP(30),DYSIGP(30)
      COMMON/INPUT1/IBDY,IBMO,IBYR,NDY,TDIR,
     A          POLLAT,IHOUR,IMO,
     A         NDYDUR,NDYDTA,WTYPE,DTABT,DTABB,DTABL,DTABR,
     A     LBAAT,LMAAT,LTAAT,ALATT,ALATB,ALONL
      COMMON/SOST/TSLATS,TSLONS,SPRED1,
     A SPRED,SPREAD,ALPHA,BETA,T,R2,IJK
C**MAXIMUM NUMBER OF STATIONS
      DATA MXNSTA/ 80/
      DATA OBS,ANA/3HOBS,3HANA/
      DATA BACK/4HBACK/
      DATA SJTAG/1H ,1H.,1H+,1H*,1H-/
      DATA ITS,ITPDY,IMM/8,2,5/
      ISNAP=0
      CALL    INPUT   ( NTPDY, TSDUR, RADIUS, ICNTMN, ICNTMX, MBIP, MEIP,
     Z MXNO, NO, OID, OLAT, OLON, WIOROT, IHRINP, NLVLA, NTSPDY,
     Z NTS, NMM,ERSO2,ERSUL)
C**SET ITAB FORWARD/BACKWARD TO 1 FOR FORWARD, 2 FOR BACKWARD
      ITABFB=1
      IF (TDIR .EQ. BACK) ITABFB=2
C
C**LOOP THROUGH NUMBER OF DAYS
      DO 400 M=1,NDY
      CALL    DTABKO   ( M, MXNSTA, NTPDY, NMM, NSTA,NSTA2,NSTA3,
     A ITABFB,NDYDTA,
     Z ITPDY, IMM, DTABT, DTABB, DTABL, DTABR, LBAAT, LMAAT,LTAAT,
     Z OLAT    ,OLON,    SID,SID2,SID3)
C
C**LOOP THROUGH NUMBER OF DAYS
C
      DO 399 IO=1,NO
C
C
C**LOOP THROUGH NUMBER OF TRAJECTORIES PER DAY
      DO 300 N=1,4,NTPDY
```

```
        IALL=0
      IF(N.EQ.1) K=1
      IF(N.EQ.3) K=2
      KKT=K
      IF (ITABFB .EQ. 2) GO TO 32
      MM=1
      KK=1
      KKT=1
      MMT=1
      KK2=1
      MM2=1
      KK3=1
      MM3=1
      KK4=1
      MM4=1
      GO TO 33
   32 MM=NMM
      KK=4
C
C**LOOP THROUGH NUMBER OF TRAJECTORY SEGMENTS
   33 DO 299 J = 1, NTS
      IF(J.EQ.1) GO TO 40
      IF (TSLAT .LE. 900) GO TO 42
C**TRAJECTORY HAS BEEN TERMINATED
C**DUE TO INSUFFICIENT AMOUNT OF INPUT DATA-
C**TERMINATION CODE INFORMATION
C**REPLACES ALL REMAINING TRAJECTORY SEGMENT LAT,LON VALUES
      GO TO 200
C ************INITIALIZATION*************************
   40 TLAT11=OLAT(IO)
      TLAT12=OLAT(IO)
      TLAT13=OLAT(IO)
      TLAT14=OLAT(IO)
      TLON11=OLON(IO)
      TLON12=OLON(IO)
      TLON13=OLON(IO)
      TLON14=OLON(IO)
      SPRD11=0.
      SPRD21=0.
      SPRD31=0.
      SPRD41=0.
      SPRE1=0.
      SPRE2=0.
      SPRE3=0.
      SPRE4=0.
   42 JTAG=0
      JTG2=0
      JTG3=0
      JTG4=0
      CALL    KKMM    ( J, N, M, KK, MM, NMM, NDYDTA, NTSPDY,ITABFB,IRTNS)
      IF (IRTNS .EQ. 90) GO TO 90
C**TRAJECTORY TERMINATED DUE TO NO DATA READ INTO DATA-BLOCK(DTABK)
C**OR CLOSEST-TIME(CLSTM) CALCULATION OUTSIDE DATA-BLOCK
   86 TTLAT1=996
      TTLAT2=996
      TTLAT3=996
      TTLAT4=996
      TTLON1=9996
      TTLON2=9996
      TTLON3=9996
      TTLON4=9996
      UBAR1=0.0
      UBAR2=0.0
      UBAR3=0.0
      UBAR4=0.0
      SPREA1=0.0
      SPREA2=0.0
      SPREA3=0.0
      SPREA4=0.0
      ALPHA1=99.
      ALPHA2=99.
      ALPHA3=99.
      ALPHA4=99.
      BETA1=99.
      BETA2=99.
      BETA3=99.
      BETA4=99.
      T1=99.
      T2=99.
      T3=99.
      T4=99.
      R21=99.
      R22=99.
      R23=99.
      R24=99.
      IJK1=0
      IJK2=0
      IJK3=0
      IJK4=0
      ICNT1=0
      ICNT2=0
      ICNT3=0
      ICNT4=0
      SICNT1=SJTAG(1)
      SICNT2=SJTAG(1)
      SICNT3=SJTAG(1)
      SICNT4=SJTAG(1)
      GO TO 200
   90 IF(K.EQ.1)  GO TO 1100
      IF(K.EQ.2)  GO TO 1300
C*************BIGINNING OF K=1  LOOP***********
 1100 IF(J.LE.2) GO TO 1110
      IF(J.GE.3.AND.J.LF. 4) GO TO 1120
      IF(J.GE.5.AND.J.LF.6) GO TO 1130
      IF(J.GE.7.AND.J.LF.8) GO TO 1140
 1110 CALL DIS02(J,K,M,KK,MM,MXNSTA,NSTA2,ITABFB,ITS,
     ZITPDY,IMM,RADIUS,TSDUR,MBIP,MFIP,SLATT,SLONT,TLAT11,TLON11,XAWT,
     Z YAWT,XXSIG,YYSIG,KK2,MM2,SJTAG,JTG2,ICNTMN,ICNTMX,XIP,YIP,
     Z XTSIP,YTSIP,DXSIGP,DYSIGP,WIP,TSLAT2,TSLON2,ISNAP,WIOROT,
     Z UBART,SIGMAH,ICNTT,SICNTT,SPRD11,SPRED2,ALPHAA,BETAA,TA,R2A,IJKA,
     ZIRTNS)
      IF(IRTNS.EQ.170) GO TO 170
      CALL ALTUTA(     SJTAG,JTG2,        TSLAT2,TSLON2,UBART,SIGMAH,ICNTT,
     Z SICNTT,ALPHAA,BETAA,TA,R2A,IJKA,IRTNS)
      IF(IRTNS.EQ.170) GO TO 170
      CALL CLSTM(J,KK,MM,JTG2,NTPDY,ITABFB,M,NDYDTA,NMM,KK2,MM2,IRTNS)
      IF(IRTNS.EQ.90) GO TO 90
      IF(IRTNS.EQ.86) GO TO 86
 1120 GO TO 1310
 1130 GO TO 1320
 1140 GO TO 1330
C *****END OF K=1 LOOP  ****************
   91 CONTINUE
C    ******BIGINNING OF K=2 LOOP ******
 1300 IF(J.LE.2) GO TO 1310
      IF(J.GE.3.AND.J.LE.4) GO TO 1320
      IF(J.GE.5.AND.J.LE. 6)  GO TO 1330
      IF(J.GE. 7.AND.J.LE. 8) GO TO 1340
 1310 CALL DISO (J,K,M,KK,MM,MXNSTA,NSTA .ITABFB, ITS,
     ZITPDY,IMM,RADIUS,TSDUR,MBIP,MFIP,SLATT,SLONT,TLAT11,TLON11,XAWT,
     Z YAWT,XXSIG,YYSIG,KKT,MMT,SJTAG,JTAG,ICNTMN,ICNTMX,XIP,YIP,
     Z XTSIP,YTSIP,DXSIGP,DYSIGP,WIP,TSLAT2,TSLON2,ISNAP,WIOROT,
     Z UBART,SIGMAH,ICNTT,SICNTT,SPRD11,SPRED2,ALPHAA,BETAA,TA,R2A,IJKA,
     Z IRTNS)
      IF(IRTNS.EQ.170) GO TO 170
      CALL ALTUTA(     SJTAG,JTAG,         TSLAT2,TSLON2,UBART,SIGMAH,ICNTT,
     Z SICNTT,ALPHAA,BETAA,TA,R2A,IJKA,IRTNS)
      IF(IRTNS.EQ.170) GO TO 170
  555 CALL CLSTM(J,KK,MM,JTAG,NTPDY,ITABFB,M,NDYDTA,NMM,KKT,MMT,IRTNS)
      IF(IRTNS.EQ.90) GO TO 90
      IF(IRTNS.EQ.86) GO TO 86
  170 CALL          CONVER(TSLAT2,TSLON2,UBART,ICNTT,SICNTT,SPRE1,SIGMAH,
     Z                     SPRED2,ALPHAA,BETAA,TA,R2A,IJKA,TSLAT,TSLON,
     Z                     UBAR,ICNT,SICNT)
      TTLAT1=TSLAT
      TTLAT2=TSLAT
      TTLAT3=TSLAT
      TTLAT4=TSLAT
      TTLON1=TSLON
      TTLON2=TSLON
      TTLON3=TSLON
      TTLON4=TSLON
      UBAR1=UBAR
      UBAR2=UBAR
      UBAR3=UBAR
      UBAR4=UBAR
      ALPHA1=ALPHA
      ALPHA2=ALPHA
      ALPHA3=ALPHA
      ALPHA4=ALPHA
      BETA1=BETA
      BETA2=BETA
      BETA3=BETA
      BETA4=BETA
      T1=T
      T2=T
      T3=T
      T4=T
      R21=R2
      R22=R2
      R23=R2
      R24=R2
      IJK1=IJK
      IJK2=IJK
      IJK3=IJK
      IJK4=IJK
      ICNT1=ICNT
      ICNT2=ICNT
      ICNT3=ICNT
      ICNT4=ICNT
      SICNT1=SICNT
      SICNT2=SICNT
      SICNT3=SICNT
      SICNT4=SICNT
      TLAT11=TSLAT5
      TLAT12=TSLAT5
      TLAT13=TSLAT5
      TLAT14=TSLAT5
      TLON11=TSLON5
      TLON12=TSLON5
      TLON13=TSLON5
      TLON14=TSLON5
      SPRD11=SPRED1
      SPRD21=SPRED1
      SPRD31=SPRED1
      SPRD41=SPRED1
      SPRE1=SPRED
      SPRE2=SPRED
      SPRE3=SPRED
      SPRE4=SPRED
      SPREA1=SPREAD
      SPREA2=SPREAD
      SPREA3=SPREAD
      SPREA4=SPREAD
      GO TO 200
   87 TTLAT1=996
      TTLAT3=996
      TTLON1=9996
      TTLON3=9996
      UBAR1=0.
      UBAR3=0.
      SPREA1=0.
      SPREA3=0.
      ALPHA1=99.
      ALPHA3=99.
      BETA1=99.
      BETA3=99.
      T1=T
      T3=T
      R21=99.
      R23=99.
      IJK1=IJK
      IJK3=IJK
      ICNT1=ICNT
      ICNT3=ICNT
      SICNT1=SJTAG(1)
      SICNT3=SJTAG(1)
      GO TO 1321
   92 CONTINUE
 1320 CALL DIS02(J,K.M,KK,MM,MXNSTA,NSTA2,ITABFB, ITS.
     ZITPDY,IMM,RADIUS,TSDUR,MBIP,MEIP,SLATT,SLONT,TLAT11,TLON11.XAWT,
     Z YAWT,XXSIG,YYSIG,KK2,MM2,SJTAG,JTG2,ICNTMN,ICNTMX,XIP,YIP,
     Z XTSIP,YTSIP,DXSIGP,DYSIGP,WIP,TSLAT2,TSLON2,ISNAP,WIOROT,
     Z UBART,SIGMAH,ICNTT,SICNTT,SPRD11,SPRED2,ALPHAA,BETAA,TA.R2A,IJKA,
     Z IRTNS)
      IF(IRTNS.EQ.170) GO TO 171
      CALL ALTDTA(     SJTAG.JTG2.        TSLAT2.TSLON2,UBART,SIGMAH,ICNTT.
     Z SICNTT,ALPHAA.BETAA.TA.R2A,IJKA,IRTNS)
      IF(IRTNS.EQ.170) GO TO 171
  141 CALL CLSTM(J,KK,MM,JTG2,NTPDY,ITABFB,M,NDYDTA,NMM,KK2,MM2,IRTNS)
      IF(IRTNS.EQ.90) GO TO 92
      IF(IRTNS.EQ.86) GO TO 87
  171 CALL         CONVER(TSLAT2,TSLON2,UBART.ICNTT,SICNTT,SPRE1.SIGMAH,
     Z                    SPRED2.ALPHAA,BETAA,TA,R2A,IJKA,TSLAT.TSLON.
     Z                    UBAR,ICNT,SICNT)
      TTLAT1=TSLAT
      TTLAT3=TSLAT
      TTLON1=TSLON
      TTLON3=TSLON
      UBAR1=UBAR
      UBAR3=UBAR
      ALPHA1=ALPHA
      ALPHA3=ALPHA
      BETA1=BETA
      BETA3=BETA
      T1=T
      T3=T
      R21=R2
      R23=R2
      IJK1=IJK
      IJK3=IJK
      ICNT1=ICNT
      ICNT3=ICNT
      SICNT1=SICNT
      SICNT3=SICNT
      TLAT11=TSLAT5
      TLAT13=TSLAT5
      TLON11=TSLON5
      TLON13=TSLON5
      SPRD11=SPRED1
      SPRD31=SPRED1
      SPRE1=SPRED
      SPRE3=SPRED
      SPREA1=SPREAD
      SPREA3=SPREAD
      GO TO 1321
   88 TTLAT2=996
      TTLAT4=996
      TTLON2=9996
      TTLON4=9996
      UBAR2=0.
      UBAR4=0.
      ALPHA2=99.
      ALPHA4=99.
      BETA2=99.
      BETA4=99.
      T2=99.
      T4=99.
      R22=99.
      R24=99.
      IJK2=0
      IJK4=0
      ICNT2=0
      ICNT4=0
      SICNT2=SJTAG(1)
      SICNT4=SJTAG(1)
      GO TO 200
   93 CONTINUE
 1321 CALL DISO3(J,K,M,KK,MM,MXNSTA,NSTA3,ITABFB, ITS,
     ZITPDY,IMM,RADIUS,TSDUR,MBIP,MEIP,SLATT,SLONT,TLAT12,TLON12,XAWT,
     Z YAWT,XXSIG,YYSIG,KK3,MM3,SJTAG,JTG3,ICNTMN,ICNTMX,XIP,YIP,
     Z XTSIP,YTSIP,DXSIGP,DYSIGP,WIP,TSLAT2,TSLON2,ISNAP,WIOROT,
     Z UBART,SIGMAH,ICNTT,SICNTT,SPRD21,SPRED2,ALPHAA,BETAA,TA,R2A,IJKA,
     Z IRTNS)
      IF(IRTNS.EQ.170) GO TO 172
      CALL ALTUTA(     SJTAG,JTG3,        TSLAT2,TSLON2,UBART,SIGMAH,ICNTT,
     Z SICNTT,ALPHAA,BETAA,TA,R2A,IJKA,IRTNS)
      IF(IRTNS.EQ.170) GO TO 172
      CALL CLSTM(J,KK,MM,JTG3,NTPDY,ITABFH,M,NDYDTA,NMM,KK3,MM3,IRTNS)
      IF(IRTNS.EQ.90) GO TO 93
      IF(IRTNS.EQ.86) GO TO 88
  172 CALL        CONVER(TSLAT2,TSLON2,UBART,ICNTT,SICNTT,SPRE2,SIGMAH,
     Z                   SPRED2,ALPHAA,BETAA,TA,R2A,IJKA,TSLAT,TSLON,
     Z                   UBAR,ICNT,SICNT)
      TTLAT2=TSLAT
      TTLAT4=TSLAT
      TTLON2=TSLON
      TTLON4=TSLON
      UBAR2=UBAR
      UBAR4=UBAR
      ALPHA2=ALPHA
      ALPHA4=ALPHA
      BETA2=BETA
      BETA4=BETA
      T2=T
      T4=T
      R22=R2
      R24=R2
      IJK2=IJK
      IJK4=IJK
      ICNT2=ICNT
      ICNT4=ICNT
      SICNT2=SICNT
      SICNT4=SICNT
      TLAT12= TSLAT5
      TLAT14= TSLAT5
      TLON12=TSLON5
      TLON14=TSLON5
      SPRD21=SPRED1
      SPRD41=SPRED1
      SPRE2=SPRED
      SPRE4=SPRED
      SPREA2=SPREAD
      SPREA4=SPREAD
      GO TO 200
   89 TTLAT1=996
      TTLAT3=996
      TTLON1=9996
      TTLON3=9996
      UBAR1=0.
      UBAR3=0.
      SPREA1=0.
      SPREA3=0.
      ALPHA1=99.
      ALPHA3=99.
      BETA1=99.
      BETA3=99.
      T1=99.
      T3=99.
      R21=99.
      R23=99.
      IJK1=0
      IJK3=0
      ICNT1=0
      ICNT3=0
      SICNT1=SJTAG(1)
      SICNT3=SJTAG(1)
      GO TO 1331
   94 CONTINUE
 1330 CALL DISO (J,K,M,KK,MM,MXNSTA,NSTA ,ITABFB, ITS,
     ZITPDY,IMM,RADIUS,TSDUR,MBIP,MEIP,SLATT,SLONT,TLAT11,TLON11,XAWT,
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     Z YAWT,XXSIG,YYSIG,KKT,MMT,SJTAG,JTAG,ICNTMN,ICNTMX,XIP,YIP,
     Z XTSIP,YTSIP,DXSIGP,DYSIGP,WIP,TSLAT2,TSLON2,ISNAP,WIOROT,
     Z UBART,SIGMAH,ICNTT,SICNTT,SPRD11,SPRED2,ALPHAA,BETAA,TA,R2A,IJKA,
     Z IRTNS)
      IF(IRTNS.EQ.170) GO TO 173
      CALL ALTUTA(     SJTAG,JTAG,        TSLAT2,TSLON2,UBART,SIGMAH,ICNTT,
     Z SICNTT,ALPHAA,BETAA,TA,R2A,IJKA,IRTNS)
      IF(IRTNS.EQ.170) GO TO 173
      CALL CLSTM(J,KK,MM,JTAG,NTPDY,ITABFB,M,NDYDTA,NMM,KKT,MMT,IRTNS)
      IF(IRTNS.EQ.90) GO TO 94
      IF(IRTNS.EQ.86) GO TO 89
  173 CALL          CONVER(TSLAT2,TSLON2,UBART,ICNTT,SICNTT,SPRE1,SIGMAH,
     Z                     SPRED2,ALPHAA,BETAA,TA,R2A,IJKA,TSLAT,TSLON,
     Z                     UBAR,ICNT,SICNT)
      TTLAT1=TSLAT
      TTLAT3=TSLAT
      TTLON1=TSLON
      TTLON3=TSLON
      UBAR1=UBAR
      UBAR3=UBAR
      ALPHA1=ALPHA
      ALPHA3=ALPHA
      BETA1=BETA
      BETA3=BETA
      T1=T
      T3=T
      R21=R2
      R23=R2
      IJK1=IJK
      IJK3=IJK
      ICNT1=ICNT
      ICNT3=ICNT
      SICNT1=SICNT
      SICNT3=SICNT
      TLAT11=TSLATS
      TLAT13=TSLATS
      TLON11=TSLONS
      TLON13=TSLONS
      SPRD11=SPRED1
      SPRD31=SPRED1
      SPRE1=SPRED
      SPRE3=SPRED
      SPREA1=SPREAD
      SPREA3=SPREAD
      GO TO 1331
   61 TTLAT2=996
      TTLAT4=996
      TTLON2=9996
      TTLON4=9996
      UBAR2=0.
      UBAR4=0.
      SPREA2=0.
      SPREA4=0.
      ALPHA2=99.
      ALPHA4=99.
      BETA2=99.
      BETA4=99.
      T2=99.
      T4=99.
      R22=99.
      R24=99.
      IJK2=0
      IJK4=0
      ICNT2=0
      ICNT4=0
      SICNT2=SJTAG(1)
      SICNT4=SJTAG(1)
      GO TO 200
   95 CONTINUE
 1331 CALL DISU (J,K,M,KK,MM,MXNSTA,NSTA ,ITABFB, ITS,
     ZITPDY,IMM,RADIUS,TSDUR,MBIP,MFIP,SLATT,SLONT,TLAT12,TLON12,XAWT,
     Z YAWT,XXSIG,YYSIG,KK2,MM2,SJTAG,JTG2,ICNTMN,ICNTMX,XIP,YIP,
     Z XTSIP,YTSIP,DXSIGP,DYSIGP,WIP,TSLAT2,TSLON2,ISNAP,WIOROT,
     Z UBART,SIGMAH,ICNTT,SICNTT,SPRD21,SPRED2,ALPHAA,BETAA,TA,R2A,IJKA,
     Z IRTNS)
      IF(IRTNS.EQ.170) GO TO 174
      CALL ALTUTA(     SJTAG,JTG2,        TSLAT2,TSLON2,UBART,SIGMAH,ICNTT,
     Z SICNTT,ALPHAA,BETAA,TA,R2A,IJKA,IRTNS)
      IF(IRTNS.EQ.170) GO TO 174
      CALL CLSTM(J,KK,MM,JTG2,NTPDY,ITABFB,M,NDYDTA,NMM,KK2,MM2,IRTNS)
      IF(IRTNS.EQ.90) GO TO 95
      IF(IRTNS.EQ.86) GO TO 61
  174 CALL          CONVER(TSLAT2,TSLON2,UBART,ICNTT,SICNTT,SPRE2,SIGMAH,
     Z                     SPRED2,ALPHAA,BETAA,TA,R2A,IJKA,TSLAT,TSLON,
     Z                     UBAR,ICNT,SICNT)
      TTLAT2=TSLAT
      TTLAT4=TSLAT
      TTLON2=TSLON
      TTLON4=TSLON
      UBAR2=UBAR
      UBAR4=UBAR
      ALPHA2=ALPHA
      ALPHA4=ALPHA
      BETA2=BETA
      BETA4=BETA
      T2=T
      T4=T
      R22=R2
      R24=R2
      IJK2=IJK
      IJK4=IJK
      ICNT2=ICNT
      ICNT4=ICNT
      SICNT2=SICNT
      SICNT4=SICNT
      TLAT12=TSLAT5
      TLAT14=TSLAT5
      TLON12=TSLON5
      TLON14=TSLON5
      SPRD21=SPRED1
      SPRD41=SPRED1
      SPRE2=SPRED
      SPRE4=SPRED
      SPREA2=SPREAD
      SPREA4=SPREAD
      GO TO 200
   62 TTLAT1=996
      TTLON1=9996
      UBAR1=0.
      SPREA1=0.
      ALPHA1=99.
      BETA1=99.
      T1=99.
      R21=99.
      IJK1=0
      ICNT1=0
      SICNT1=SJTAG(1)
      GO TO 1341
   96 CONTINUE
 1340 CALL DIS02(J,K,M,KK,MM,MXNSTA,NSTA2,ITABFB, ITS,
     ZITPDY,IMM,RADIUS,TSDUR,MHIP,MFIP,SLATT,SLONT,TLAT11,TLON11,XAWT,
     Z YAWT,XXSIG,YYSIG,KKT,MMT,SJTAG,JTAG,ICNTMN,ICNTMX,XIP,YIP,
     Z XTSIP,YTSIF,DXSIGP,DYSIGP,WIP,TSLAT2,TSLON2,ISNAP,WIOROT,
     Z UBART,SIGMAH,ICNTT,SICNTT,SPRD11,SPRED2,ALPHAA,BETAA,TA,R2A,IJKA,
     Z IRTNS)
      IF(IRTNS.EQ.170) GO TO 175
      CALL ALTDTA(     SJTAG,JTAG,        TSLAT2,TSLON2,UBART,SIGMAH,ICNTT,
     Z SICNTT,ALPHAA,BETAA,TA,R2A,IJKA,IRTNS)
      CALL CLSTM(J,KK,MM,JTAG,NTPDY,ITABFB,M,NDYDTA,NMM,KKT,MMT,IRTNS)
      IF(IRTNS.EQ.90) GO TO 96
      IF(IRTNS.EQ.86) GO TO 62
  175 CALL          CONVER(TSLAT2,TSLON2,UBART,ICNTT,SICNTT,SPRE1,SIGMAH,
     Z                     SPRED2,ALPHAA,BETAA,TA,R2A,IJKA,TSLAT,TSLON,
     Z                     UBAR,ICNT,SICNT)
  510 TTLAT1=TSLAT
      TTLON1=TSLON
      UBAR1=UBAR
      ALPHA1=ALPHA
      BETA1=BETA
      T1=T
      R21=R2
      IJK1=IJK
      ICNT1=ICNT
      SICNT1=SICNT
      TLAT11=TSLAT5
      TLON11=TSLON5
      SPRD11=SPRED1
      SPRE1=SPRED
      SPREA1=SPREAD
      GO TO 1341
   63 TTLAT2=996
      TTLON2=9996
      UBAR2=0.
      SPREA2=0.
      ALPHA2=99.
      BETA2=99.
      T2=T
      R22=99.
      IJK2=0
      ICNT2=0
      SICNT2=SJTAG(1)
      GO TO 1342
   97 CONTINUE
 1341 CALL DIS02(J,K,M,KK,MM,MXNSTA,NSTA2,ITABFB, ITS,
     ZITPDY,IMM,RADIUS,TSDUR,MHIP,MFIP,SLATT,SLONT,TLAT12,TLON12,XAWT,
     Z YAWT,XXSIG,YYSIG,KK2,MM2,SJTAG,JTG2,ICNTMN,ICNTMX,XIP,YIP,
     Z XTSIP,YTSIP,DXSIGP,DYSIGP,WIP,TSLAT2,TSLON2,ISNAP,WIOROT,
     Z UBART,SIGMAH,ICNTT,SICNTT,SPRD21,SPRED2,ALPHAA,BETAA,TA,R2A,IJKA,
     Z IRTNS)
      IF(IRTNS.EQ.170) GO TO 176
      CALL ALTDTA(     SJTAG,JTG2,        TSLAT2,TSLON2,UBART,SIGMAH,ICNTT,
     Z SICNTT,ALPHAA,BETAA,TA,R2A,IJKA,IRTNS)
      IF(IRTNS.EQ.170) GO TO 176
      CALL CLSTM(J,KK,MM,JTG2,NTPDY,ITABFB,M,NDYDTA,NMM,KK2,MM2,IRTNS)
      IF(IRTNS.EQ.90) GO TO 97
      IF(IRTNS.EQ,86) GO TO 63
 176  CALL        CONVER(TSLAT2,TSLON2,UBART,ICNTT,SICNTT,SPRE2,SIGMAH,
     Z                   SPRED2,ALPHAA,BETAA,TA,R2A,IJKA,TSLAT,TSLON,
     Z                   UBAR,ICNT,SICNT)
 512  TTLAT2=TSLAT
      TTLON2=TSLON
      UBAR2=UBAR
      ALPHA2=ALPHA
      BETA2=BETA
      T2=T
      R22=R2
      IJK2=IJK
      ICNT2=ICNT
      SICNT2=SICNT
      TLAT12=TSLAT5
      TLON12=TSLON5
      SPRD21=SPRED1
      SPRE2=SPRED
      SPREA2=SPREAD
      GO TO 1342
  64  TTLAT3=996
      TTLON3=9996
      UBAR3=0.
      SPREA3=0.
      ALPHA3=99.
      BETA3=99.
      T3=99.
      R23=99.
      IJK3=0
      ICNT3=0
      SICNT3=SJTAG(1)
      GO TO 1343
  98  CONTINUE
1342  CALL DIS03(J,K,M,KK,MM,MXNSTA,NSTA3,ITABFB, ITS,
     ZITPDY,IMM,RADIUS,TSDUR,MBIP,MEIP,SLATT,SLONT,TLAT13,TLON13,XAWT,
     Z YAWT,XXSIG,YYSIG,KK3,MM3,SJTAG,JTG3,ICNTMN,ICNTMX,XIP,YIP,
     Z XTSIP,YTSIP,DXSIGP,DYSIGP,WIP,TSLAT2,TSLON2,ISNAP,WIOROT,
     Z UBART,SIGMAH,ICNTT,SICNTT,SPRD31,SPRED2,ALPHAA,BETAA,TA,R2A,IJKA,
     Z IRTNS)
      IF(IRTNS.EQ. 170) GO TO 177
      CALL ALTUTA(     SJTAG,JTG3,       TSLAT2,TSLON2,UBART,SIGMAH,ICNTT,
     Z SICNTT,ALPHAA,BETAA,TA,R2A,IJKA,IRTNS)
      IF(IRTNS.EQ.170) GO TO 177
      CALL CLSTM(J,KK,MM,JTG3,NTPDY,ITABFB,M,NDYDTA,NMM,KK3,MM3,IRTNS)
      IF(IRTNS.EQ.90) GO TO 98
      IF(IRTNS.EQ,86) GO TO 64
 177  CALL        CONVER(TSLAT2,TSLON2,UBART,ICNTT,SICNTT,SPRE3,SIGMAH,
     Z                   SPRED2,ALPHAA,BETAA,TA,R2A,IJKA,TSLAT,TSLON,
     Z                   UBAR,ICNT,SICNT)
 514  TTLAT3=TSLAT
      TTLON3=TSLON
      UBAR3=UBAR
      ALPHA3=ALPHA
      BETA3=BETA
      T3=T
      R23=R2
      IJK3=IJK
      ICNT3=ICNT
      SICNT3=SICNT
      TLAT13=TSLAT5
      TLON13=TSLON5
      SPPD31=SPRED1
      SPRE3=SPRED
      SPREA3=SPREAD
      GO TO 1343
  65  TTLAT4=996
      TTLON4=9996
      UBAR4=0.
      SPREA4=0.
      ALPHA4=99.
      BETA4=99.
      T4=99.
      R24=99.
      IJK4=0
      ICNT4=0
      SICNT4=SJTAG(1)
      GO TO 200
  99  CONTINUE
1343  CALL DIS03(J,K,M,KK,MM,MXNSTA,NSTA3,ITABFB,ITS,
     ZITPDY,IMM,RADIUS,TSDUR,MBIP,MEIP,SLATT,SLONT,TLAT14,TLON14,XAWT,
     Z YAWT,XXSIG,YYSIG,KK4,MM4,SJTAG,JTG4,ICNTMN,ICNTMX,XIP,YIP,
     Z XTSIP,YTSIP,DXSIGP,DYSIGP,WIP,TSLAT2,TSLON2,ISNAP,WIOROT,
     Z UBART,SIGMAH,ICNTT,SICNTT,SPRD41,SPRED2,ALPHAA,BETAA,TA,R2A,IJKA,
     Z IRTNS)
      IF(IRTNS.EQ.170) GO TO 178
      CALL ALTUTA(     SJTAG,JTG4,       TSLAT2,TSLON2,UBART,SIGMAH,ICNTT,
     Z SICNTT,ALPHAA,BETAA,TA,R2A,IJKA,IRTNS)
      IF(IRTNS.EQ.170) GO TO 178
      CALL CLSTM(J,KK,MM,JTG4,NTPDY,ITABFB,M,NDYDTA,NMM,KK4,MM4,IRTNS)
      IF(IRTNS.EQ.90) GO TO 99
      IF(IRTNS.EQ.86) GO TO 65
 178  CALL        CONVER(TSLAT2,TSLON2,UBART,ICNTT,SICNTT,SPRE4,SIGMAH,
     Z                            SPRED2,ALPHAA,BETAA,TA,R2A,IJKA,TSLAT,TSLON,
     Z                            UBAR,ICNT,SICNT)
  516 TTLAT4=TSLAT
      TTLON4=TSLON
      UBAR4=UBAR
      ALPHA4=ALPHA
      BETA4=BETA
      T4=T
      R24=R2
      IJK4=IJK
      ICNT4=ICNT
      SICNT4=SICNT
      TLAT14=TSLAT5
      TLON14=TSLON5
      SPRD41=SPRED1
      SPRE4=SPRED
      SPREA4=SPREAD
C      END OF K=2  LOOP **********
  200 CONTINUE
      IF(IO.EQ.1) GO TO 201
      IF(IO.EQ.2) GO TO 202
      IF(IO.EQ.3) GO TO 203
      IF(IO.EQ.4) GO TO 204
      IF(IO.EQ.5) GO TO 205
  201 KUNIT=21
      GO TO 210
  202 KUNIT=25
      GO TO 210
  203 KUNIT=29
      GO TO 210
  204 KUNIT=33
      GO TO 210
  205 KUNIT=37
  210  IF(IALL.EQ.999) GO TO 300
        IF(TTLAT1.GT.450.AND.TTLAT2.GT.450.AND.TTLAT3.GT.450.AND.
     Z  TTLAT4.GT.450) GO TO 250
        IF(TTLAT1.LT.350.AND.TTLAT2.LT.350.AND.TTLAT3.LT.350.AND.
     Z  TTLAT4.LT.350) GO TO 250
        IF(TTLON1.LT.750.AND.TTLON2.LT.750.AND.TTLON3.LT.750.AND.
     Z  TTLON4.LT.350) GO TO 250
        IF(TTLON1.GT.950.AND.TTLON2.GT.950.AND.TTLON3.GT.950.AND.
     Z  TTLON4.GT.950) GO TO 250
        GO TO 255
  250   IALL=999
  255 WRITE(KUNIT) TTLAT1,TTLON1,UBAR1,SPREA1,ALPHA1,BETA1,T1,R21,IJK1
     Z ,IALL
      WRITE(6,2500) TTLAT1,TTLON1,UBAR1,SPREA1,ALPHA1,BETA1,T1,R21,
     Z IJK1,KUNIT
 2500 FORMAT(1X,2I10,6F15.3,2I10)
      KUNIT=KUNIT+1
      WRITE(KUNIT) TTLAT2,TTLON2,UBAR2,SPREA2,ALPHA2,BETA2,T2,R22,IJK2
     Z ,IALL
      WRITE(6,2500) TTLAT2,TTLON2,UBAR2,SPREA2,ALPHA2,BETA2,T2,R22,
     Z IJK2,KUNIT
      KUNIT=KUNIT+1
      WRITE(KUNIT) TTLAT3,TTLON3,UBAR3,SPREA3,ALPHA3,BETA3,T3,R23,IJK3
     Z ,IALL
      WRITE(6,2500) TTLAT3,TTLON3,UBAR3,SPREA3,ALPHA3,BETA3,T3,R23,
     Z IJK3,KUNIT
      KUNIT=KUNIT+1
      WRITE(KUNIT) TTLAT4,TTLON4,UBAR4,SPREA4,ALPHA4,BETA4,T4,R24,IJK4
     Z ,IALL
      WRITE(6,2500) TTLAT4,TTLON4,UBAR4,SPREA4,ALPHA4,BETA4,T4,R24,
     Z IJK4,KUNIT
  299 CONTINUE
  300 CONTINUE
  399 CONTINUE
  400 CONTINUE
      DO 475 I=1,5
      WRITE(14) OID(I),OLAT(I),OLON(I),WIDROT(I),ERSO2(I),ERSUL(I)
  475 CONTINUE
      WRITE(14)  NO,NDY,NTS,NTPDY,LTAAT,LMAAT,LBAAT
      WRITE(14) TSDUR,ALATT,ALONL
      STOP
      END


      SUBROUTINE ALTDTA(SJTAG, JTAG, TSLAT2, TSLON2, UBART, SIGMAH,
     Z ICNTT, SICNTT, ALPHAA, BETAA, TA, R2A, IJKA, IRTNS)
C
C**ALTERNATE DATA SELECTION
C
      LOGICAL SJTAG(5),SICNTT
      DATA OBS,ANA/3HOBS,3HANA/
      IRTNS=0
      JTAG=JTAG+1
      IF (JTAG .LE. 4) RETURN
      JTAGT=5
      TSLAT2=99.9
      TSLON2=999.9
      UBART=0.
      SIGMAH=0.
      ALPHAA=99.
      BETAA=99.
      TA=99.
      R2A=99.
      IJKA=0
      ICNTT=ICNTT
      SICNTT=SJTAG(JTAGT)
      IRTNS=170
      RETURN
      END


      SUBROUTINE AWIND(SHT, SATH, DI, LBAAT, LTAAT, WHT, XW, YW, NLVL,
     Z XAW, YAW, XSIGMA, YSIGMA)
C
C**AVERAGE WINDS
C
      INTEGER      SHT,SATH,BTH,TTH,TH
      INTEGER WHT(50)
      DIMENSION XW(50),YW(50)
      DIMENSION MHT(100)
      LB=SHT+LBAAT
      IF (LBAAT .NE. 0 .OR. DI .GT. 60. .OR. SHT .GT. SATH)LB=SATH+LBAAT
      LT=SATH+LTAAT
      STHXW=0.
      STHYW=0.
      STH=0.
C**CALCULATE M HEIGHTS FOR WIND LEVELS
      IF(NLVL.EQ.1) GO TO 21
      MLVL=NLVL*2-1
      DO 12 M=1,MLVL,2
        MDM=(M+1)/2
      MHT(M)=WHT(MDM)
   12 CONTINUE
C**CALCULATE M HEIGHTS FOR MID LEVELS
      DO 14 M=2,MLVL,2
      MHT(M)=(MHT(M-1)+MHT(M+1))/2
   14 CONTINUE
C**DETERMINE M LAYER FOR LB
      IF(LB.GE.MHT(1)) GO TO 18
      M=1
      GO TO 30
   18 DO 20 M=2,MLVL
      IF(LB.LT.MHT(M)) GO TO 30
   20 CONTINUE
   21 XAW=99.
      YAW=99.
      XSIGMA=99.
      YSIGMA=99.
      RETURN
C**CALCULATE WEIGHT SUMS AT LB
   30 MLB=M
      BTH=MHT(M)-LB
        MDM=(M+1)/2
      STHXW=STHXW+BTH*XW(MDM)
      STHYW=STHYW+BTH*YW(MDM)
      STH=STH+BTH
C**DETERMINE M LAYER FOR LT
      IF(LT.LE.MHT(MLVL)) GO TO 48
      MM=MLVL
      GO TO 70
   48 MLVLM1=MLVL-1
      DO 50 M=1,MLVLM1
      MM=MLVL-M
      IF(LT.GT.MHT(MM)) GO TO 70
   50 CONTINUE
      XAW=99.
      YAW=99.
      XSIGMA=99.
      YSIGMA=99.
      RETURN
C**CALCULATE WEIGHT SUMS AT LT
   70 MMLTM1=MM-1
      TTH=LT-MHT(MM)
          MDM=(MM+2)/2
      STHXW=STHXW+TTH*XW(MDM)
      STHYW=STHYW+TTH*YW(MDM)
      STH=STH+TTH
      IF(MLB.GT.MMLTM1) GO TO 300
C**CALCULATE INTERMEDIATE WEIGHT SUMS
      DO 100 M=MLB,MMLTM1
      TH=MHT(M+1)-MHT(M)
        MDM=(M+2)/2
      STHXW=STHXW+TH*XW(MDM)
      STHYW=STHYW+TH*YW(MDM)
      STH=STH+TH
  100 CONTINUE
  300 IF(STH.EQ.0.) STH=.00001
      XAW=STHXW/STH
      YAW=STHYW/STH
      XSIGMA=0.
      YSIGMA=0.
      DO 101 M=MLB,MMLTM1
      TH=MHT(M+1)-MHT(M)
        MDM=(M+2)/2
      XSIGMA=XSIGMA+TH*(XW(MDM)-XAW)**2
      YSIGMA=YSIGMA+TH*(YW(MDM)-YAW)**2
  101 CONTINUE
      IF(XSIGMA.LT.0.0.OR.YSIGMA.LT.0.0) GO TO 500
      AXAW=ABS(XAW)
      AYAW=ABS(YAW)
      IF(AXAW.GT.9999.9.OR.AYAW.GT.9999.9) GO TO 500
      IF(STH.LE.0.0) GO TO 500
      XSIGMA=SQRT(XSIGMA/STH)
      YSIGMA=SQRT(YSIGMA/STH)
      RETURN
  500 XAW=99.
      YAW=99.
      XSIGMA=99.
      YSIGMA=99.
      RETURN
      END


     SUBROUTINE BIN(LEN,$,$,$)
      COMMON/INDAT/ ODAT(510),NXTSTA,LSTSTA
      READ(2) LEN,(ODAT(I),I=1,LEN)
      RETURN 2
      END


      SUBROUTINE BOUT(LEN,$,$)
      COMMON/INDAT/ODAT(510),IEND,NXTSTA,LSTSTA
      WRITE(2) LEN,(ODAT(I),I=1,LEN)
      RETURN 2
      END


      SUBROUTINE CLSTM(J, KK, MM, JTAG, NTPDY, ITABFB, M, NDYDTA, NMM,
     Z KKT, MMT, IRTNS)
C
C**CLOSEST TIME FOR ALTERNATE DATA
C
      IRTNS=96
      IF(JTAG.EQ.4) GO TO 8
C**SECOND CLOSEST TIME, JTAG=2
      IF(ITABFB.EQ.2) GO TO 3
C**FORW TRAJECTORIES
    2 IF(MOD(J,2).EQ.0) GO TO 30
      GO TO 10
C** BACK TRAJECTORIES
    3 IF(MOD(J,2).EQ.0) GO TO 10
      GO TO 30
C**THIRD CLOSEST TIME, JTAG=4(OBS ONLY)
    8 IF(ITABFB.EQ.2) GO TO 2
      GO TO 3
   10 KKT=KK+1
      IF(KKT.LE.NTPDY) GO TO 20
      KKT=1
      MMT=MM+1
      GO TO 60
   20 MMT=MM
      GO TO 60
   30 KKT=KK-1
      IF(KKT.GE.1) GO TO 40
      KKT=NTPDY
      MMT=MM-1
      GO TO 60
   40 MMT=MM
   60 IF (MMT .LT. 1. .OR. MMT .GT. NMM) RETURN
      IF(ITABFB.EQ.2) GO TO 62
      IF (M + MMT -1 .GT. NDYDTA) RETURN
      IRTNS=90
      RETURN
   62 IF (M+MMT-1 .LT. NMM) RETURN
      IRTNS=90
      RETURN
      END


      SUBROUTINE CONVER(TSLAT2,TSLON2,UBART,ICNTT,SICNTT,SSRED,SIGMAH,
     Z                  SPRED2,ALPHAA,BETAA,TA,R2A,IJKA,TSLAT,TSLON,
     Z   UBAR,ICNT,SICNT)
      LOGICAL SICNT,SICNTT
      INTEGER TSLAT,TSLON
      COMMON/SOST/TSLATS,TSLONS,SPRED1,
     A SPRED,SPREAD,ALPHA,BETA,T,R2,IJK
      TSLAT=TSLAT2*10.+.5
      TSLON=INT(TSLON2*10.+1800.5)-1800
      UBAR=UBART+.5
      ICNT=ICNTT
      SICNT=SICNTT
      TSLAT5=TSLAT2
      TSLON5=TSLON2
      SPRED1=SPRED2
      SPRED=SSRED+SIGMAH
      SPREAD=SPRED/60.
      ALPHA=ALPHAA
      BETA=BETAA
      T=TA
      R2=R2A
      IJK=IJKA
      RETURN
      END
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      SUBROUTINE DISO(J, K, M, KK, MM, MXNSTA, NSTA, ITABFB,
     A  ITS, ITPDY, IMM, RADIUS, TSDUR, MBIP, MEIP, SLATT, SLONT, TSLAT1
     A, TSLON1, XAWT, YAWT, XXSIG, YYSIG, KKT, MMT, SJTAG, JTAG, ICNTMN,
     A ICNTMX, XIP, YIP, XTSIP, YTSIP, DXSIGP, DYSIGP, WIP, TSLAT2,
     A TSLON2, ISNAP, WIOROT    , UBART, SIGMAH, ICNTT, SICNTT, SPRED1,
     A SPRED2, ALPHAA, BETAA, TA, R2A, IJKA, IRTNS)
C
C**DISPLACEMENT CALCULATION USING OBSERVED WINDS
C
      LOGICAL SJTAG(5),SICNTT
      DIMENSION NSTA(ITPDY,IMM)
      DIMENSION XXSIG(MXNSTA),YYSIG(MXNSTA)
      DIMENSION XAWT(MXNSTA),YAWT(MXNSTA)
      DIMENSION SLATT(MXNSTA),SLONT(MXNSTA)
      INTEGER XIP(ICNTMX),YIP(ICNTMX),XTSIP(ICNTMX),YTSIP(ICNTMX),
     A        WIP(ICNTMX),XTSP,YTSP
      COMMON/STAT/SLAT ( 80,2,5), SLON (80,2,5),XAW ( 80,2,5),
     Z YAW (80,2,5),XSIGMA(80,2,5),YSIGMA(80,2,5)
      INTEGER DXSIGP(ICNTMX),DYSIGP(ICNTMX)
      DATA PI/3.14159/
      IRTNS=0
      SWXTSI=0.
      SWYTSI=0.
      SDXSIG=0.
      SDYSIG=0.
      SWI=0.
      ICNTT=0
      NEAR=0
      IF(JTAG.EQ.0) GO TO 90
      IF(NSTA(KKT,MMT).EQ.0) RETURN
      NSTADO=NSTA(KKT,MMT)
      DO 80 I=1,NSTADO
      SLATT(I)=SLAT(I,KKT,MMT)
      SLONT(I)=SLON(I,KKT,MMT)
      XAWT(I)=XAW(I,KKT,MMT)
      YAWT(I)=YAW(I,KKT,MMT)
      XXSIG(I)=XSIGMA(I,KKT,MMT)
      YYSIG(I)=YSIGMA(I,KKT,MMT)
   80 CONTINUE
      GO TO 95
   90 IF(NSTA(KK,MM).EQ.0) RETURN
      NSTADO=NSTA(KK,MM)
   95 DO 150 I=1,NSTADO
      IF (JTAG .NE. 0) GO TO 96
             SLATT(I)=55.
              SLONT(I)=55.
              XAWT(I)=66.
              YAWT(I)=66.
              XXSIG(I)=77.
              YYSIG(I)=77.
   96 CALL    ITSIW   ( JTAG, RADIUS, SLAT(I,KK,MM), SLON(I,KK,MM),
     Z SLATT(I), SLONT(I), XAW(I,KK,MM), YAW(I,KK,MM), XSIGMA(I,KK,MM),
     Z YSIGMA(I, KK, MM), XAWT(I), YAWT(I),XXSIG(I), YYSIG(I), TSDUR,
     Z TSLAT1, TSLON1, ITABFB, NEAR, XI, YI, XTSI, YTSI, DXSIGI, DYSIGI,
     Z WI, IJRTNS)
      IF (IJRTNS .EQ. 150) GO TO  150
      ICNTT=ICNTT+1
      XIP(ICNTT)=XI+.5
      YIP(ICNTT)=YI+.5
      XTSIP(ICNTT)=XTSI/3.+.5
      YTSIP(ICNTT)=YTSI/3.+.5
      DXSIGP(ICNTT)=DXSIGI/3.+0.5
      DYSIGP(ICNTT)=DYSIGI/3.+0.5
      WIP(ICNTT)=WI*1000000.
      SWXTSI=SWXTSI+WI*XTSI
      SWYTSI=SWYTSI+WI*YTSI
      SDXSIG=SDXSIG+WI*DXSIGI
      SDYSIG=SDYSIG+WI*DYSIGI
      SWI=SWI+WI
  150 CONTINUE
      IF(ICNTT .LT. ICNTMN .AND. NEAR .NE. 1) RETURN
C**NOT SUFFICIENT OBSERVED WINDS
C**TRAJECTORY SEGMENT DISPLACEMENT**************************************
      IF (SWI .EQ. 0.) SWI=.0001
      XTS=SWXTSI/SWI
      YTS=SWYTSI/SWI
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      XSDX=SDXSIG/SWI
      YSDY=SDYSIG/SWI
      XTSP=XTS/3.+.5
      YTSP=YTS/3.+.5
      TSLAT2=TSLAT1+YTS/60.
      TSLON2=TSLON1-XTS/(60.*COS(TSLAT1*PI/180.))
      UBART=.515*SQRT(XTS*XTS+YTS*YTS)/TSDUR
      UBARTT=UBART/0.515
      SIGMAH=(ABS(XTS)*YSDY+ABS(YTS)*XSDX)/(UBARTT*TSDUR)
      SPRED2=SPRED1+SIGMAH
      CALL XSZ(TSLAT1,TSLON1,TSLAT2,TSLON2,XTS,YTS,SPRED2,ALPHAA,BETAA,
     A     IJKA,R2A,TA,WIOROT)
      SICNTT=SJTAG(JTAG+1)
      IF (M .GE. MBIP .AND. M .LE. MEIP) GO TO 172
      IRTNS=170
      RETURN
  172 IF(ISNAP .EQ. 1) GO TO 175
C**PRINT TRAJECTORY SEGMENT DISPLACEMENT AND****************************
C**INDIVIDUAL STATION RELATIVE LOCATIONS AND DISPLACEMENTS**************
      IF(ISNAP.EQ.1) GO TO 175
      ISNAP=1
      WRITE(6,173)
  173 FORMAT(1H ,*  J  K  M TAG CNT XTS YTS*/
     A       1H ,*                                XI    YI XTSIYTSI WI*,
     A           *        XI    YI XTSIYTSI WI    XI    YI XTSIYTSI WI*,
     A           *        XI    YI XTSIYTSI WI*)
  175 WRITE(6,180) J,K,M,JTAG,ICNTT,XTSP,YTSP,
     A        (XIP(IP),YIP(IP),XTSIP(IP),YTSIP(IP),WIP(IP),IP=1,ICNTT)
  180 FORMAT(1H ,3I3,4I4/
     A       1H ,25X,4(3X,2I5,3I4)/1H ,25X,4(3X,2I5,3I4)/
     A       1H ,25X,4(3X,2I5,3I4)/1H ,25X,4(3X,2I5,3I4)/
     A       1H ,25X,4(3X,2I5,3I4)/1H ,25X,4(3X,2I5,3I4)/
     A       1H ,25X,4(3X,2I5,3I4)/1H ,25X,4(3X,2I5,3I4))
      IRTNS=170
      RETURN
      END


      SUBROUTINE DISO2(J,K,M,KK,MM,MXNSTA,NSTA2,ITABFR,
     A  ITS, ITPDY, IMM, RADIUS, TSDUR, MBIP, MEIP, SLATT, SLONT, TSLAT1
     A, TSLON1, XAWT, YAWT, XXSIG, YYSIG, KKT, MMT, SJTAG, JTAG, ICNTMN,
     A ICNTMX, XIP, YIP, XTSIP, YTSIP, DXSIGP, DYSIGP, WIP, TSLAT2,
     A TSLON2, ISNAP, WIOROT    , UBART, SIGMAH, ICNTT, SICNTT, SPRED1,
     A SPRED2, ALPHAA, BETAA, TA, R2A, IJKA, IRTNS)
      DIMENSION NSTA2(ITPDY,IMM)
      DIMENSION XXSIG(MXNSTA),YYSIG(MXNSTA)
      DIMENSION XAWT(MXNSTA),YAWT(MXNSTA)
      DIMENSION SLATT(MXNSTA),SLONT(MXNSTA)
      INTEGER XIP(ICNTMX),YIP(ICNTMX),XTSIP(ICNTMX),YTSIP(ICNTMX),
     A        WIP(ICNTMX),XTSP,YTSP
      COMMON/STAT2/SLAT2(80,2,5), SLON2(80,2,5),XAW2( 80,2,5),
     Z YAW2(80,2,5),XSIGM2(80,2,5),YSIGM2(80,2,5)
      INTEGER DXSIGP(ICNTMX),DYSIGP(ICNTMX)
      LOGICAL SJTAG(5),SICNTT
      DATA PI/3.14159/
      IRTNS=0
      SWXTSI=0.
      SWYTSI=0.
      SDXSIG=0.
      SDYSIG=0.
      SWI=0.
      ICNTT=0
      NEAR=0
      IF(JTAG.EQ.0) GO TO 90
      IF(NSTA2(KKT,MMT).EQ.0) RETURN
      NSTADO=NSTA2(KKT,MMT)
      DO 80 I=1,NSTADO
      SLATT(I)=SLAT2(I,KKT,MMT)
      SLONT(I)=SLON2(I,KKT,MMT)
      XAWT(I)=XAW2(I,KKT,MMT)
      YAWT(I)=YAW2(I,KKT,MMT)
      XXSIG(I)=XSIGM2(I,KKT,MMT)
      YYSIG(I)=YSIGM2(I,KKT,MMT)
   80 CONTINUE
      GO TO 95
   90 IF(NSTA2(KK,MM).EQ.0) RETURN
      NSTADO=NSTA2(KK,MM)
   95 DO 150 I=1,NSTADO
      IF (JTAG .NE. 0) GO TO 96
          SLATT(I)=55.
            SLONT(I)=55.
            XAWT(I)=66.
            YAWT(I)=66.
            XXSIG(I)=77.
            YYSIG(I)=77.
   96 CALL ITSIW(JTAG,RADIUS,SLAT2(I,KK,MM),SLON2(I,KK,MM),
     ZSLATT(I), SLONT(I),XAW2(I,KK,MM),YAW2(I,KK,MM),XSIGM2(I,KK,MM),
     Z YSIGM2(I, KK, MM), XAWT(I), YAWT(I),XXSIG(I), YYSIG(I), TSDUR,
     Z TSLAT1, TSLON1, ITABFR, NEAR, XI, YI, XTSI, YTSI, DXSIGI, DYSIGI,
     Z WI, IJRTNS)
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      IF (IJRTNS .EQ. 150) GO TO  150
      ICNTT=ICNTT+1
      XIP(ICNTT)=XI+.5
      YIP(ICNTT)=YI+.5
      XTSIP(ICNTT)=XTSI/3.+.5
      YTSIP(ICNTT)=YTSI/3.+.5
      DXSIGP(ICNTT)=DXSIGI/3.+0.5
      DYSIGP(ICNTT)=DYSIGI/3.+0.5
      WIP(ICNTT)=WI*1000000.
      SWXTSI=SWXTSI+WI*XTSI
      SWYTSI=SWYTSI+WI*YTSI
      SDXSIG=SDXSIG+WI*DXSIGI
      SDYSIG=SDYSIG+WI*DYSIGI
      SWI=SWI+WI
  150 CONTINUE
      IF(ICNTT .LT. ICNTMN .AND. NEAR .NE. 1) RETURN
C**NOT SUFFICIENT OBSERVED WINDS
C**TRAJECTORY SEGMENT DISPLACEMENT***********************************
      IF (SWI .EQ. 0.) SWI=.0001
      XTS=SWXTSI/SWI
      YTS=SWYTSI/SWI
      XSDX=SDXSIG/SWI
      YSDY=SDYSIG/SWI
      XTSP=XTS/3.+.5
      YTSP=YTS/3.+.5
      TSLAT2=TSLAT1+YTS/60.
      TSLON2=TSLON1-XTS/(60.*COS(TSLAT1*PI/180.))
      UBART=.515*SQRT(XTS*XTS+YTS*YTS)/TSDUR
      UBARTT=UBART/0.515
      SIGMAH=(ABS(XTS)*YSDY+ABS(YTS)*XSDX)/(UBARTT*TSDUR)
      SPRED2=SPRED1+SIGMAH
      CALL XSZ(TSLAT1,TSLON1,TSLAT2,TSLON2,XTS,YTS,SPRED2,ALPHAA,BETAA,
     A        IJKA,R2A,TA,WIOROT)
      SICNTT=SJTAG(JTAG+1)
      IF (M .GE. MBIP .AND. M .LE. MEIP) GO TO 172
      IRTNS=170
      RETURN
  172 IF(ISNAP .EQ. 1) GO TO 175
      IF(ISNAP.EQ.1) GO TO 175
      ISNAP=1
      WRITE(6,173)
  173 FORMAT(1H ,*  J  K  M TAG CNT XTS YTS*/
     A         1H ,*                                  XI    YI XTSIYTSI WI*,
     A             *              XI    YI XTSIYTSI WI    XI    YI XTSIYTSI WI*,
     A             *              XI    YI XTSIYTSI W+*)
  175 WRITE(6,180) J,K,M,JTAG,ICNTT,XTSP,YTSP,
     A            (XIP(IP),YIP(IP),XTSIP(IP),YTSIP(IP),WIP(IP),IP=1,ICNTT)
  180 FORMAT(1H ,3I3,4I4/
     A         1H ,25X,4(3X,2I5,3I4)/1H ,25X,4(3X,2I5,3I4)/
     A         1H ,25X,4(3X,2I5,3I4)/1H ,25X,4(3X,2I5,3I4)/
     A         1H ,25X,4(3X,2I5,3I4)/1H ,25X,4(3X,2I5,3I4)/
     A         1H ,25X,4(3X,2I5,3I4)/1H ,25X,4(3X,2I5,3I4))
       IRTNS=170
       RETURN
       END


      SUBROUTINE DISO3(J,K,M,KK,MM,MXNSTA,NSTA3,ITABFR,
     A  ITS, ITPDY, IMM, RADIUS, TSDUR, MBIP, MEIP, SLATT, SLONT, TSLAT1
     A, TSLON1, XAWT, YAWT, XXSIG, YYSIG, KKT, MMT, SJTAG, JTAG, ICNTMN,
     A ICNTMX, XIP, YIP, XTSIP, YTSIP, DXSIGP, DYSIGP, WIP, TSLAT2,
     A TSLON2, ISNAP, WIOROT    , UBART, SIGMAH, ICNTT, SICNTT, SPRED1,
     A SPRED2, ALPHAA, BETAA, TA, R2A, IJKA, IRTNS)
      DIMENSION NSTA3(ITPDY,IMM)
      DIMENSION XXSIG(MXNSTA),YYSIG(MXNSTA)
      DIMENSION XAWT(MXNSTA),YAWT(MXNSTA)
      DIMENSION SLATT(MXNSTA),SLONT(MXNSTA)
      INTEGER XIP(ICNTMX),YIP(ICNTMX),XTSIP(ICNTMX),YTSIP(ICNTMX),
     A        WIP(ICNTMX),XTSP,YTSP
      COMMON/STAT3/SLAT3(80,2,5), SLON3(80,2,5),XAW3( 80,2,5),
     Z YAW3(80,2,5),XSIGM3(80,2,5),YSIGM3(80,2,5)
      INTEGER DXSIGP(ICNTMX),DYSIGP(ICNTMX)
      LOGICAL SJTAG(5),SICNTT
      DATA PI/3.14159/
      IRTNS=0
      SWXTSI=0.
      SWYTSI=0.
      SDXSIG=0.
      SDYSIG=0.
      SWI=0.
      ICNTT=0
      NEAR=0
      IF(JTAG.EQ.0) GO TO 90
      IF(NSTA3(KKT,MMT).EQ.0) RETURN
      NSTADO=NSTA3(KKT,MMT)
      DO 80 I=1,NSTADO
      SLATT(I)=SLAT3(I,KKT,MMT)
      SLONT(I)=SLON3(I,KKT,MMT)
      XAWT(I)=XAW3(I,KKT,MMT)
      YAWT(I)=YAW3(I,KKT,MMT)
      XXSIG(I)=XSIGM3(I,KKT,MMT)
      YYSIG(I)=YSIGM3(I,KKT,MMT)
   80 CONTINUE
      GO TO 95
   90 IF(NSTA3(KK,MM).EQ.0) RETURN
      NSTADO=NSTA3(KK,MM)
   95 DO 150 I=1,NSTADO
      IF (JTAG .NE. 0) GO TO 96
          SLATT(I)=55.
           SLONT(I)=55.
           XAWT(I)=66.
           YAWT(I)=66.
           XXSIG(I)=77.
           YYSIG(I)=77.
   96 CALL ITSIW(JTAG,RADIUS,SLAT3(I,KK,MM),SLON3(I,KK,MM),
     ZSLATT(I), SLONT(I),XAW3(I,KK,MM),YAW3(I,KK,MM),XSIGM3(I,KK,MM),
     Z YSIGM3(I, KK, MM), XAWT(I), YAWT(I),XXSIG(I), YYSIG(I), TSDUR,
     Z TSLAT1, TSLON1, ITABFB, NEAR, XI, YI, XTSI, YTSI, DXSIGI, DYSIGI,
     Z WI, IJRTNS)
      IF (IJRTNS .EQ. 150) GO TO  150
      ICNTT=ICNTT+1
      XIP(ICNTT)=XI+.5
      YIP(ICNTT)=YI+.5
      XTSIP(ICNTT)=XTSI/3.+.5
      YTSIP(ICNTT)=YTSI/3.+.5
      DXSIGP(ICNTT)=DXSIGI/3.+0.5
      DYSIGP(ICNTT)=DYSIGI/3.+0.5
      WIP(ICNTT)=WI*1000000.
      SWXTSI=SWXTSI+WI*XTSI
      SWYTSI=SWYTSI+WI*YTSI
      SDXSIG=SDXSIG+WI*DXSIGI
      SDYSIG=SDYSIG+WI*DYSIGI
      SWI=SWI+WI
  150 CONTINUE
      IF(ICNTT .LT. ICNTMN .AND. NEAR .NE. 1) RETURN
C**NOT SUFFICIENT OBSERVED WINDS
C**TRAJECTORY SEGMENT DISPLACEMENT*************************************
      IF (SWI .EQ. 0.) SWI=.0001
      XTS=SWXTSI/SWI
      YTS=SWYTSI/SWI
      XSDX=SDXSIG/SWI
      YSDY=SDYSIG/SWI
      XTSP=XTS/3.+.5
      YTSP=YTS/3.+.5
      TSLAT2=TSLAT1+YTS/60.
      TSLON2=TSLON1-XTS/(60.*COS(TSLAT1*PI/180.))
      UBART=.515*SQRT(XTS*XTS+YTS*YTS)/TSDUR
      UBARTT=UBART/0.515
      SIGMAH=(ABS(XTS)*YSDY+ABS(YTS)*XSDX)/(UBARTT*TSDUR)
      SPRED2=SPRED1+SIGMAH
      CALL XSZ(TSLAT1,TSLON1,TSLAT2,TSLON2,XTS,YTS,SPRED2,ALPHAA,BETAA,
     A      IJKA,R2A,TA,WIOROT)
      SICNTT=SJTAG(JTAG+1)
      IF (M .GE. MBIP .AND. M .LE. MEIP) GO TO 172
      IRTNS=170
      RETURN
  172 IF(ISNAP .EQ. 1) GO TO 175
      IF(ISNAP.EQ.1) GO TO 175
      ISNAP=1
      WRITE(6,173)
  173 FORMAT(1H ,*  J  K  M TAG CNT XTS YTS*/
     A        1H ,*                                XI    YI XTSIYTSI WI*,
     A           *          XI    YI XTSIYTSI WI   XI    YI XTSIYTSI WI*,
     A           *          XI    YI XTSIYTSI W+*)
  175 WRITE(6,180) J,K,M,JTAG,ICNTT,XTSP,YTSP,
     A            (XIP(IP),YIP(IP),XTSIP(IP),YTSIP(IP),WIP(IP),IP=1,ICNTT)
  180 FORMAT(1H ,3I3,4I4/
     A        1H ,25X,4(3X,2I5,3I4)/1H ,25X,4(3X,2I5,3I4)/
     A        1H ,25X,4(3X,2I5,3I4)/1H ,25X,4(3X,2I5,3I4)/
     A        1H ,25X,4(3X,2I5,3I4)/1H ,25X,4(3X,2I5,3I4)/
     A        1H ,25X,4(3X,2I5,3I4)/1H ,25X,4(3X,2I5,3I4))
      IRTNS=170
      RETURN
      END


      SUBROUTINE DTABKO(M, MXNSTA, NTPDY, NMM, NSTA,NSTA2,NSTA3,
     Z ITABFB,NDYDTA,
     Z ITPDY, IMM, DTABT, DTABB, DTABL, DTABR, LBAAT, LMAAT,LTAAT,OLAT,
     Z OLON, SID,SID2,SID3)
C
C**DATA BLOCK FOR OBSERVED INFORMATION
C
      DIMENSION NSTA(ITPDY,IMM),NSTA2(ITPDY,IMM),NSTA3(ITPDY,IMM)
      INTEGER SID(MXNSTA,ITPDY)
      INTEGER SID2(MXNSTA,ITPDY),SID3 (MXNSTA,ITPDY)
      INTEGER SI(80),SI2(80),SI3(80)
      DIMENSION SLA (80),SLO (80),XA (80),YA (80),XS (80),YS (80)
      DIMENSION SLA2(80),SLO2(80),XA2(80),YA2(80),XS2(80),YS2(80)
      DIMENSION SLA3(80),SLO3(80),XA3(80),YA3(80),XS3(80),YS3(80)
      COMMON/STAT/SLAT ( 80,2,5), SLON (80,2,5),XAW ( 80,2,5),
     Z YAW (80,2,5),XSIGMA(80,2,5),YSIGMA(80,2,5)
      COMMON/STAT2/SLAT2(80,2,5), SLON2(80,2,5),XAW2( 80,2,5),
     Z YAW2(80,2,5),XSIGM2(80,2,5),YSIGM2(80,2,5)
      COMMON/STAT3/SLAT3(80,2,5), SLON3(80,2,5),XAW3( 80,2,5),
     Z YAW3(80,2,5),XSIGM3(80,2,5),YSIGM3(80,2,5)
      COMMON /DATERD/IDMO,IDYR,IDDY,IDHR,NRSTA,NREC,IM
      COMMON/FLAG/IFLAG
      IF(M.GT.1) GO TO 5
      WRITE(6,4)
    4 FORMAT(1H ,27X,*NUMBER OF   NUMBER     NUMBER OF*/
     B       1H ,27X,*REPORTING      OF      STATIONS IN*/
     C       1H ,27X,* STATIONS   RECORDS    BOUNDARIES*)
    5 DO 200 MM=1,NMM
      GO TO (1,2),ITABFB
    1 IF(M.EQ.1) GO TO 8
      IF(M+MM-1.GT.NDYDTA) GO TO 200
      GO TO 3
    2 IF(M+MM-1.LT.NMM) GO TO 200
    3 IF(MM.EQ.NMM) GO TO 8
      DO 10 N=1,4,NTPDY
      IF(N.EQ.1) K=1
      IF(N.EQ.3) K=2
      NSTAT=NSTA(K,MM+1)
      NSTA(K,MM)=NSTAT
      DO 9 I=1,NSTAT
      SLAT(I,K,MM)=SLAT(I,K,MM+1)
      SLON(I,K,MM)=SLON(I,K,MM+1)
      XAW(I,K,MM)=XAW(I,K,MM+1)
      YAW(I,K,MM)=YAW(I,K,MM+1)
      XSIGMA(I,K,MM)=XSIGMA(I,K,MM+1)
      YSIGMA(I,K,MM)=YSIGMA(I,K,MM+1)
    9 CONTINUE
      NSTAT2=NSTA2(K,MM+1)
      NSTA2(K,MM)=NSTAT2
      DO 11 I=1,NSTAT2
      SLAT2(I,K,MM)=SLAT2(I,K,MM+1)
      SLON2(I,K,MM)=SLON2(I,K,MM+1)
      XAW2(I,K,MM)=XAW2(I,K,MM+1)
      YAW2(I,K,MM)=YAW2(I,K,MM+1)
      XSIGM2(I,K,MM)=XSIGM2(I,K,MM+1)
      YSIGM2(I,K,MM)=YSIGM2(I,K,MM+1)
   11 CONTINUE
      NSTAT3=NSTA3(K,MM+1)
      NSTA3(K,MM)=NSTAT3
      DO 12 I=1,NSTAT3
      SLAT3(I,K,MM)=SLAT3(I,K,MM+1)
      SLON3(I,K,MM) =SLON3(I,K,MM+1)
      XAW3(I,K,MM)=XAW3(I,K,MM+1)
      YAW3(I,K,MM)=YAW3(I,K,MM+1)
      XSIGM3(I,K,MM)=XSIGM3(I,K,MM+1)
      YSIGM3(I,K,MM)=YSIGM3(I,K,MM+1)
   12 CONTINUE
   10 CONTINUE
      GO TO 200
    8 DO 199 N=1,4,NTPDY
      IF(N.EQ.1)  K=1
      IF(N.EQ.3) K=2
      IFLAG=1
      CALL POSTP(M,MM,K)
      CALL    RDAVO   ( MXNSTA, DTABT, DTABB, DTABL, DTABR, LBAAT, LTAAT,
     Z OLAT,OLON,SI ,SLA ,SLO ,XA ,YA ,XS ,YS ,NSTA (K,MM))
      DO 101 I=1,80
      SID (I,K)=SI(I)
      SLAT (I,K,MM)=SLA(I)
      SLON (I,K,MM)=SLO(I)
      XAW (I,K,MM)=XA(I)
      YAW (I,K,MM)=YA(I)
      XSIGMA(I,K,MM)=XS(I)
      YSIGMA(I,K,MM)=YS(I)
  101 CONTINUE
      IFLAG=2
      REWIND 2
      CALL  POSTP(M,MM,K)
      CALL  RDAVO(MXNSTA,DTABT,DTABB,DTABL,DTABR,LBAAT,LMAAT,
     Z OLAT,OLON,SI2,SLA2,SLO2,XA2,YA2,XS2,YS2,NSTA2(K,MM))
      DO 102 I=1,80
      SID2(I,K)=SI2(I)
      SLAT2(I,K,MM)=SLA2(I)
      SLON2(I,K,MM)=SLO2(I)
      XAW2(I,K,MM)=XA2(I)
      YAW2(I,K,MM)=YA2(I)
      XSIGM2(I,K,MM)=XS2(I)
      YSIGM2(I,K,MM)=YS2(I)
  102 CONTINUE
      REWIND 2
      CALL  POSTP(M,MM,K)
      CALL  RDAVO(MXNSTA,DTABT,DTABB,DTABL,DTABR,LMAAT,LTAAT,
     Z OLAT,OLON,SI3,SLA3,SLO3,XA3,YA3,XS3,YS3,NSTA3(K,MM))
      DO 103 I=1,80
      SID3(I,K)=SI3(I)
      SLAT3(I,K,MM)=SLA3(I)
      SLON3(I,K,MM)=SLO3(I)
      XAW3(I,K,MM)=XA3(I)
      YAW3(I,K,MM)=YA3(I)
      XSIGM3(I,K,MM)=XS3(I)
      YSIGM3(I,K,MM)=YS3(I)
  103 CONTINUE
      REWIND 2
  199 CONTINUE
  200 CONTINUE
      RETURN
      END


      SUBROUTINE INPUT(NTPDY, TSDUR, RADIUS, ICNTMN, ICNTMX, MBIP, MEIP,
     Z MXNO, NO, OID, OLAT, OLON, WIOROT, IHRINP, NLVLA, NTSPDY,
     Z NTS, NMM,ERSO2,ERSUL)
C
C**INPUT INFORMATION
C
         DIMENSION ERSO2(5).ERSUL(5)
      DIMENSION OID(5),OLAT(5),OLON(5),WIOROT(10)
      COMMON/INPUT1/IBDY,IBMO,IBYR,NDY,TDIR,
     A          POLLAT,IHOUR,IMO,
     A         NDYDUR,NDYDTA,WTYPE,DTABT,DTABB,DTABL,DTABR,
     A   LBAAT,LMAAT,LTAAT,ALATT,ALATB,ALONL
C
C*****************************************************************
C**INPUT DATA CARDS***********************************************
C**CARD 0**
C**NUMBER OF ORIGINS
      READ(5,100) NO,NDY
  100 FORMAT(I2,1X,I2)
C**CARD 1**
C**ORIGIN IDENTIFIED BY LETTERS(OID), LATITUDE(OLAT), LONGITUDE(OLON)
      DO 101 I=1,5
      READ(5,1) OID(I),OLAT(I),OLON(I),WIOROT(I),ERSO2(I),ERSUL(I)
    1 FORMAT(A3,1X,F4.1,1X,F6.1,1X,F10.1,1X,F10.0,1X,F10.0)
  101 CONTINUE
C**CARD 2**
C**DATE COMPUTATIONS BEGIN: DAY(IBDY), MONTH(IBMO), YEAR(IBYR)
C**NUMBER OF DAYS COMPUTATIONS DESIRED(NDY)
      READ(5,2) IBDY,IMO,IBYR,IHOUR,IBMO
    2 FORMAT(4(I2,1X),2X,A3)
C**CARD 3**
C**DIRECTION IN TIME(TDIR), FORWARD(FORW), BACKWARD(BACK)
C**DURATION IN DAYS(NDYDUR)
      READ(5,3) TDIR,NDYDUR
    3 FORMAT(A4,1X,I2)
C**CARD 4**
C**NUMBER OF DAYS OF WIND INPUT DATA(NDYDTA)
      READ(5,4) NDYDTA
    4 FORMAT(I2)
C**CARD 5**
C**TYPE OF WIND INPUT DATA(WTYPE)
C**OBSERVED(OBS), ANALYZED(ANA),OBSERVED AND ANALYZED(O,A)
      READ(5,5) WTYPE
    5 FORMAT(A3)
C**CARD 6**
C**BOUNDARIES FOR OBSERVED WIND INPUT DATA
C**TOP LATITUDE(DTABT), BOTTOM LATITUDE(DTABB),
C**LEFT LONGITUDE(DTABL), RIGHT LONGITUDE(DTABR)
      READ(5,6) DTABT,DTABB,DTABL,DTABR
    6 FORMAT(F4.1,1X,F4.1,1X,F6.1,1X,F6.1)
C**CARD 8**
C**TRANSPORT LAYER BASE(LBAAT), AND TOP(LTAAT) IN METERS
C**ABOVE AVERAGE TERRAIN
      READ(5,8) LBAAT,LTAAT,LMAAT
    8 FORMAT(I4,1X,I4,1X,I4)
C**CARD 9**
C**BOUNDARIES FOR MAPS IN SUBROUTINES:
C** LATITUDE OF MAP    TOP BOUNDARY(ALATT)
C** LATITUDE OF MAP BOTTOM BOUNDARY(ALATB)
C**LONGITUDE OF MAP   LEFT BOUNDARY(ALONL)
C**(MAP WIDTH IN LONGITUDINAL DEGREES IS OBTAINED FROM
C    SEPARATE TABULATION)
      READ(5,9) ALATT,ALATB,ALONL
    9 FORMAT(F4.1,1X,F4.1,1X,F6.1)
C**END INPUT DATA CARDS*******************************************
C*****************************************************************
C
C*****************************************************************
C**INPUT PARAMETERS***********************************************
C**NUMBER OF TRAJECTORIES PER DAY
      NTPDY=2
C**TRAJECTORY SEGMENT DURATION IN HOURS
      TSDUR=6.
C**RADIUS IN NAUTICAL MILES FOR INCLUDING OBSERVED WINDS
C**IN DISPLACEMENT CALCULATIONS
      RADIUS=300.

C**MINIMUM NUMBER OF STATIONS WITHIN RADIUS
C**FOR A DISPLACEMENT CALCULATION
      ICNTMN=2
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C**MAXIMUM NUMBER OF STATIONS WITHIN RADIUS
C**FOR A DISPLACEMENT CALCULATION
      ICNTMX=30
C**LATITUDE ABOVE WHICH DISTANCES ARE CALCULATED
C  IN A POLAR COORDINATE SYSTEM
      POLLAT=60.
C**BEGINNING AND ENDING M IN M=1,NDY LOOP FOR PRINTING
C**TRAJECTORY SEGMENT DISPLACEMENTS AND INDIVIDUAL STATION
C**RELATIVE LOCATIONS AND DISPLACEMENTS
      MBIP=0
      MEIP=0
C**PRINTING INTERVAL IN HOURS
      IHRINP=12
C**NUMBER OF ANALYSIS LEVELS
      NLVLA=4
C**END INPUT PARAMETERS*************************************************
C**********************************************************************
C
C**NUMBER OF TRAJECTORY SEGMENTS PER DAY
      NTSPDY=24/TSDUR
C**NUMBER OF TRAJECTORY SEGMENTS
      NTS=8
C**NUMBER OF DAYS IN DATA BLOCK (DTABK)
      NMM=NDYDUR+1
C**PRINT INPUT DATA CARD INFORMATION
      WRITE(6,20) (OID(IO),OLAT(IO),OLON(IO),IO=1,NO)
      WRITE(6,21) IBDY,IBMO,IBYR,NDY,
     3            TDIR,NDYDUR,
     4            NDYDTA,
     5            WTYPE,
     6            DTABT,DTABB,DTABL,DTABR,
     8            LBAAT,LTAAT
   20 FORMAT(1H1,16X,*INPUT FOR TRAJECTORY COMPUTATIONS*/
     A1H ,*INPUT*/1H ,* DATA*/1H ,* CARD*/
     11H ,4X,41H1 ORIGIN ******************************* ,
     A   A3,*(*,F4.1,1X,F6.1,*)*/10(46X,A3,*(*,F4.1,1X,F6.1,*)*/))
   21 FORMAT(
     21H ,4X,41H2 DATE THAT COMPUTATIONS BEGIN ********* ,I2,1X,A3,1X,I
     B2/
     B1H ,4X,41H  NUMBER OF DAYS COMPUTATIONS DESIRED ** ,I2/
     31H ,4X,41H3 DIRECTION IN TIME ******************** ,A4/
     A1H ,4X,41H  DURATION IN DAYS ********************* ,I2/
     41H ,4X,41H4 NUMBER OF DAYS OF WIND INPUT DATA **** ,I2/
     51H ,4X,41H5 TYPE OF WIND INPUT DATA ************** ,A3/
     61H ,4X,41H6 BOUNDARIES FOR OBSERVED WIND INPUT DATA/
     A1H ,4X,41H  TOP AND BOTTOM LATTITUDES ************ ,2X,F4.1,
     A           3X,F4.1/
     B1H ,4X,41H  LEFT AND RIGHT LONGITUDES ************ ,F6.1,1X,F6.1/
     81H ,4X,30H8 TRANSPORT LAYER BASE AND TOP/
     A1H ,4X,41H  IN METERS ABOVE AVERAGE TERRAIN ****** ,I4,1X,I4)
      WRITE(6,25) ALATT,ALATB,ALONL
   25 FORMAT(
     91H ,4X,36H9 BOUNDARIES FOR MAPS IN SUBROUTINES/
     A1H ,4X,41H  TOP LATITUDE ************************* ,2X,F4.1/
     B1H ,4X,41H  BOTTOM LATITUDE ********************** ,2X,F4.1/
     C1H ,4X,41H  LEFT LONGITUDE *********************** ,F6.1)
      WRITE(6,30)
   30 FORMAT(1H1)
      RETURN
      END


      SUBROUTINE ITSIW(JTAG, RADIUS, SLAT, SLON, SLATT, SLONT, XAW, YAW,
     Z XSIGMA, YSIGMA, XAWT, YAWT, XXSIG, YYSIG, TSDUR, TSLAT1, TSLON1,
     Z ITABFB, NEAR, X, Y, XTS, YTS, DXSIG, DYSIG, W, IJRTNS)
C
C**CONTRIBUTION TO A TRAJECTORY SEGMENT
C**FROM AN INDIVIDUAL STATION AND ITS WEIGHT
C
      DATA PI/3.14159/
      IJRTNS=150
      IF(JTAG.EQ.0) GO TO 3
      SLATSH=SLATT
      SLONSH=SLONT
      GO TO 5
    3 SLATSH=SLAT
      SLONSH=SLON
    5 X=(TSLON1-SLONSH)*60.*COS(SLATSH*PI/180.)
      Y=(SLATSH-TSLAT1)*60.
      D=SQRT(X*X+Y*Y)
      IF (D .GT. RADIUS) RETURN
      IF(JTAG.EQ.0) GO TO 10
      IF (XAWT .EQ. 99.) RETURN
      GO TO 12
   10 IF (XAW .EQ. 99.) RETURN
   12 IF(D.LE.RADIUS/2.) NEAR=1
      IF(JTAG.EQ.0) GO TO 20
      XAWSH=XAWT
      YAWSH=YAWT
      XXSIGS=XXSIG
      YYSIGS=YYSIG
      GO TO 18
   20 XAWSH=XAW
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      YAWSH=YAW
      XXSIGS=XSIGMA
      YYSIGS=YSIGMA
   18 GO TO (21,22),ITABFB
   21 XTS=1.94*XAWSH*TSDUR
      YTS=1.94*YAWSH*TSDUR
      DXSIG=1.94*XXSIGS*TSDUR
      DYSIG=1.94*YYSIGS*TSDUR
      GO TO 23
   22 XTS=-1.94*XAWSH*TSDUR
      YTS=-1.94*YAWSH*TSDUR
      DXSIG=-1.94*XXSIGS*TSDUR
      DYSIG=-1.94*YYSIGS*TSDUR
   23 CONTINUE
      DTS=SQRT(XTS*XTS+YTS*YTS)
      XW=-X+XTS/2.
      YW= Y-YTS/2.
      DWSQ=XW*XW+YW*YW
      IF(DWSQ.EQ.0.) DWSQ=.0001
      DISTW=1./DWSQ
      ALINW=1.
      IF(D .NE. 0. .AND. DTS .NE. 0.) ALINW=1.-.5*ABS((YTS*X-XTS*Y)/
     Z  (DTS*D+ .0001))
      W=DISTW*ALINW
      IJRTNS=0
      RETURN
      END


      SUBROUTINE KKMM(J, K, M, KK, MM, NMM, NDYDTA, NTSPDY,ITABFB,IRTNS)
C
C**DETERMINE PROPER TRAJECTORY SEGMENT
C**TIME OF DAY(KK) AND DAY(MM) IN DATA BLOCK DTABK
C
      IRTNS=0
      KKS=KK
      IF (ITABFB .EQ. 2) GO TO 52
      KKT=1.+.5*FLOAT(J)+K-1
      KK=MOD(KKT-1,4)+1
      IF(KK.LT.KKS) MM=MM+1
      IF(M+MM-1.LE.NDYDTA) IRTNS=90
      RETURN
   52 KKT=5.5-.5*FLOAT(MOD(J-1,NTSPDY)+1)+K-1
      KK=MOD(KKT-1,4)+1
      IF(KK.GT.KKS) MM=MM-1
      IF(M+MM-1.GE.NMM) IRTNS=90
      RETURN
      END


      SUBROUTINE POSTP(M,MM,K)
C
C**POSITION TAPES FOR STARTING RUN AT DESIGNATED BEGINNING TIME
C
      COMMON/INPUT1/IBDY,IBMO,IBYR,NDY,TDIR,
     A           POLLAT,IHOUR,IMO,
     A          NDYDUR,NDYDTA,WTYPE,DTABT,DTABB,DTABL,DTABR,
     A   LBAAT,LMAAT,LTAAT,ALATT,ALATB,ALONL
      COMMON /DATERD/IDMO,IDYR,IDDY,IDHR,NRSTA,NREC,IM
      COMMON /INDAT/ODAT(510),IEND,NXTSTA,LSTSTA
      IEND=0
    5 CALL RDDATE
      IF(IEND.NE.0) STOP 333
      IF(M.NE.1.OR.MM.NE.1.OR.K.NE.1) GO TO 100
      IF(IM.NE.IMO) GO TO 5
      IF(IDDY.NE.IBDY) GO TO 5
      IF(IDHR.NE.IHOUR) GO TO 5
  100 RETURN
      END


      SUBROUTINE RDAVO(MXNSTA, DTABT, DTABB, DTABL, DTABR, LBAAT, LTAAT,
     Z OLAT, OLON, SID, SLAT, SLON, XAW, YAW, XSIGMA, YSIGMA, NSTA)
C
C**READ AND AVERAGE OBSERVED WINDS
C
      INTEGER SID(MXNSTA),SIDT,SHT,SATH
      INTEGER WHT(50)
      DIMENSION SLAT(MXNSTA),SLON(MXNSTA)
      DIMENSION XAW(MXNSTA),YAW(MXNSTA)
      DIMENSION XSIGMA(MXNSTA),YSIGMA(MXNSTA)
      DIMENSION XW(50),YW(50)
      COMMON /DATERD/IDMO,IDYR,IDDY,IDHR,NRSTA,NREC,IM
      COMMON /STHDRD/ISTNO,ALAT,ALON,ISTH,ISATH,NLVL
      COMMON /INDAT/ODAT(510),IEND,NXTSTA,LSTSTA
      COMMON /WINDRD/WDS(3,50)
      DATA PI/3.14159/
      WRITE(6,15) IDYR,IDMO,IDDY,IDHR,NRSTA,NREC
   15 FORMAT(1H ,9X,I4,1X,A3,1X,I2,*-*,I2,*Z*,6X,I4,6X,I5)
      NSTA=0
      ISOVER=MXNSTA
      IF(NRSTA.EQ.0) GO TO 110
      DO 100 IR=1,NRSTA
   56 CALL  RDSTHD
      SIDT=ISTNO
      SLATT=ALAT
      SLONT=ALON
      SHT=ISTH
      SATH=ISATH
      IF(SLATT.LE.DTABT.AND.SLATT.GE.DTABB.AND.
     A    SLONT.LE.DTABL.AND.SLONT.GE.DTABR) GO TO 40
      CALL RDWIND
      GO TO 100
   40 NSTA=NSTA+1
      IF(NSTA.LE.MXNSTA) GO TO 44
      ISOVER=ISOVER+1
      WRITE(6,42) ISOVER.MXNSTA,SIDT,SLATT,SLONT
   42 FORMAT(1H ,70X,*ISTAOVER=*,I3,2X,*MXNSTA=*,I3,
     A        3X,I5,*(*,F4.1,1X,F6.1,*)*)
      NSTA=MXNSTA
   44 CONTINUE
      I=NSTA
      SID(I)=SIDT
      SLAT(I)=SLATT
      SLON(I)=SLONT
      CALL RDWIND
      DO 50 LVL=1,NLVL
      WHT(LVL)=HDS(1,LVL)
      WDIR=HDS(2,LVL)
      WSPD=HDS(3,LVL)
      XW(LVL)=-WSPD*SIN(WDIR*PI/180.)
      YW(LVL)=-WSPD*COS(WDIR*PI/180.)
   50 CONTINUE
      XI=(OLON-SLON(I))*60.*COS(SLAT(I)*PI/180.)
      YI=(SLAT(I'-OLAT)*60.
      DI=SQRT(XI*XI+YI*YI)
   60 CALL    AWIND   ( SHT, SATH, DI, LBAAT, LTAAT, WHT, XW, YW, NLVL,
     Z XAW(I), YAW(I), XSIGMA(I), YSIGMA(I))
  100 CONTINUE
  110 WRITE(6,120) NSTA
  120 FORMAT(1H+,54X,I3)
      RETURN
      END


      SUBROUTINE RDDATE
  FOR CSU TAPES
      COMMON /DATERD/IDMO,IDYR,IDDY,IDHR,NRSTA,NREC,IM
      COMMON /INDAT/ODAT(510),IEND,NXTSTA,LSTSTA
      COMMON/FLAG/IFLAG
      DATA IZER/0/
      ISW=0
  100 IF(IFLAG.EQ.2) GO TO 120
  130    CALL TAPEX ('WINDDATA   ',1,1,IOST,510,ODAT,LEN)
         IF(IOST.EQ.0.OR.IOST.EQ.4) GO TO 114
          IF(IOST.EQ.1) GO TO 116
          GO TO 117
  120   CALL BIN(LEN,$115,$116,$117)
  116 IF(ISW.NE.0) GO TO 98
      ISW=10
      GO TO 100
  117 WRITE(6,2002) IOST
 2002 FORMAT(' FR RDDATE, I-O',O2)
      IF(IFLAG.EQ.2) GO TO 120
      GO TO 130
  114    CALL BOUT(LEN,$115,$101)
  115 ISW=0
      IF(LEN.GT.20) GO TO 100
        IDMO=ODAT(1)
      IDYR=ODAT(2)
      IDDY=ODAT(3)
      IDHR=ODAT(4)
      NRSTA=ODAT(5)
      NREC=ODAT(6)
      IM=ODAT(7)
      NXTSTA=171
      LSTSTA=171
      GO TO 99
   98 IEND=10
      GO TO 99
  101 STOP 404
   99 RETURN
      END
      SUBROUTINE RDDATA(I)
      COMMON /INDAT/ODAT(510),IEND,NXTSTA,LSTSTA
      COMMON/FLAG/IFLAG
      ISW=0
  100 IF(IFLAG.EQ.2) GO TO 120
  130 CALL TAPEX ('WINDDATA  ',1,1,IOST,510,ODAT,LEN)
        IF(IOST.EQ.0.OR.IOST.EQ.4) GO TO 114
        IF(IOST.EQ.1) GO TO 116
        GO TO 117
  120 CALL BIN (LEN,$115,$116,$117)
  116 IF(ISW.NE.0) GO TO 98
      ISW=10
      GO TO 100
  117 WRITE(6,2002) IOST
 2002 FORMAT(' FR RDDATA, I-0',02)
      IF(IFLAG.EQ.2) GO TO 120
      GO TO 130

  114   CALL BOUT(LEN,$115,$101)
  115 ISW=0
      IF(LEN.EQ.510) GO TO 150
      WRITE(6,2003) LEN
 2003 FORMAT(* FR RDDATA, BAD LEN*I10)
  150 I=I-170
      NXTSTA=NXTSTA-170
      GO TO 99
   98 IEND=10
      GO TO 99
  101 STOP 444
   99 RETURN
      END


      SUBROUTINE RDSTHD
C FOR CSU TAPES
      COMMON /STHDRD/ISTNO,ALAT,ALON,ISTH,ISATH,NLVL
      COMMON /INDAT/ODAT(510),IEND,NXTSTA,LSTSTA
      COMMON/FLAG/IFLAG
      DIMENSION DAT(3,170)
      EQUIVALENCE (ODAT(1),DAT(1))
      DATA IDUM/0/
      IF(NXTSTA.GT.170) CALL RDDATA(IDUM)
      ISTNO=DAT(1,NXTSTA)
      ALAT=DAT(2,NXTSTA)
      ALON=DAT(3,NXTSTA)
      I=NXTSTA+1
      IF(I.GT.170) CALL RDDATA(I)
      ICNT=ICNT+1
      ISTH=DAT(1,I)
      ISATH=DAT(2,I)
      NLVL=DAT(3,I)
      LSTSTA=NXTSTA
      NXTSTA=NXTSTA+(NLVL+2)
      RETURN
      END
      SUBROUTINE RDWIND
C FOR CSU TAPES
      COMMON /STHDRD/ISTNO,ALAT,ALON,ISTH,ISATH,NLVL
      COMMON /INDAT/ODAT(510),IEND,NXTSTA,LSTSTA
      COMMON /WINDRD/HDS(3,50)
      DIMENSION DAT(3,170)
      EQUIVALENCE(ODAT(1),DAT(1))
      IST=LSTSTA+2
      IF(IST.GT.170) CALL RDDATA(IST)
      IEN=IST+(NLVL-1)
      JEN=IEN
      K=0
      IF(IEN.LT.171) GO TO 150
      JEN=170
  150 DO 10 I = IST, JEN
      K=K+1
      HDS(1,K)=DAT(1,I)
      HDS(2,K)=DAT(2,I)
      HDS(3,K)=DAT(3,I)
   10 CONTINUE
      IF(JEN.EQ.IEN) GO TO 99
      CALL RDDATA(IEN)
      DO 20 I=1,IEN
      K=K+1
      HDS(1,K)=DAT(1,I)
      HDS(2,K)=DAT(2,I)
      HDS(3,K)=DAT(3,I)
   20 CONTINUE
   99 RETURN
      END
      SUBROUTINE RDWIND
  FOR CSU TAPES
      COMMON /STHDRD/ISTNO,ALAT,ALON,IST8,ISATH,NLVL
      COMMON /INDAT/ODAT(510),IEND,NXTSTA,LSTSTA
      COMMON /WINDRD/HDS(3,50)
      DIMENSION DAT(3,170)
      EQUIVALENCE(ODAT(1),DAT(1))
      IST=LSTSTA+2
      IF(IST.GT.170) CALL RDDATA(IST)
      IEN=IST+(NLVL-1)
      JEN=IEN
      K=0
      IF(IEN.LT.171) GO TO 150
      JEN=170
  150 DO 10 I = IST, JEN
      K=K+1
      HDS(1,K)=DAT(1,I)
      HDS(2,K)=DAT(2,I)
      HDS(3,K)=DAT(3,I)
   10 CONTINUE
      IF(JEN.EQ.IEN) GO TO 99
      CALL RDDATA(IEN)
      DO 20 I=1,IEN
      K=K+1
      HDS(1,K)=DAT(1,I)
      HDS(2,K)=DAT(2,I)
      HDS(3,K)=DAT(3,I)
   20 CONTINUE
   99 RETURN
      END


      SUBROUTINE XSZ(TSLAT1,TSLON1,TSLAT2,TSLON2,XTS,YTS,SPRED2,ALPHAA
     A ,BETAA,IJKA,R2A,TA,WTOROT)
C----DETERMINES THE DISTANCE,R2,AND THE ANGLES,ALPHAA,BETWEEN TRAJECTORY
C     END POINTS, AND THE DISTANCE TA, AND THE ANGLE,BETAA, BETWEEN TRAJECTORY
C    ENDPOINT AND SPREAD END POINT---------------------------
      PI=3.14159
      WORO=WTOROT/1852.0
      R2=XTS*XTS+YTS*YTS
      R2A=SQRT(R2)
      S2=(WORO/2.+SPRED2)*(WORO/2.+SPRED2)
      T2=R2+S2
      TA=SQRT(T2)
      IF(R2.EQ.0.) GO TO 101
      IF(XTS.EQ.0.) GO TO 1
      Z1=ABS(YTS/XTS)
      ALPHAA=ATAN(Z1)
      GO TO 5
    1 ALPHAA=.5*PI
    5 IF(R2A.EQ.0.) GO TO 6
      Z2=SQRT(S2/R2)
      BETAA=ATAN(Z2)
      GO TO 7
    6 BETAA=0.
    7 CONTINUE
      IF(TSLAT2.GE.TSLAT1.AND.TSLON2.LE.TSLON1) GO TO 10
      IF(TSLAT2.GE.TSLAT1.AND.TSLON2.GT.TSLON1) GO TO 20
      IF(TSLAT2.LT.TSLAT1.AND.TSLON2.GT.TSLON1) GO TO 30
      IF(TSLAT2.LT.TSLAT1.AND.TSLON2.LE.TSLON1) GO TO 40
   10 IJKA=1
      ALPHAA=ALPHAA
      RETURN
   20 IJKA=2
      ALPHAA=PI-ALPHAA
      RETURN
   30 IJKA=3
      ALPHAA=PI+ALPHAA
      RETURN
   40 IJKA=4
      ALPHAA=2.*PI-ALPHAA
      RETURN
  101 ALPHAA=0.
      BETAA=0.
      IJKA=0
      RETURN
      END
```

Program of Concentration Calculation (Model B)

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```
      PROGRAM CALCON
     1(DATA2,DATA3,OUTPUT,TAPE5=DATA2,TAPE6=OUTPUT,
     A TAPE7=DATA3,
     2  TAPE21=1002B,TAPE22=1002B,TAPE23=1002B,TAPE24=1002B,
     3TAPE25=1002B,TAPE26=1002B,TAPE27=1002B,TAPE28=1002B,TAPE29=1002B,
     4TAPE30=1002B,TAPE31=1002B,TAPE32=1002B,TAPE33=1002B,TAPE34=1002B,
     5TAPE35=1002B,TAPE36=1002B,TAPE37=1002B,TAPE38=1002B,TAPE39=1002B,
     6TAPE40=1002B,TAPE14=1002B,TAPE50,TAPE51=1002B,TAPE52)
C
C   THIS PROGRAM WILL READ IN DATA COMPUTED FROM THE PREVEOUS PROGRAM
C   TO  COMPUTE THE RESULTANT CONCENTRATIONS ETC.
C
      COMMON /OUTPUT1/ TSLAT(8,2,5),TSLON(8,2,5),UBAR(8,2,5),
     Z  SPREAD(8,2,5)
      COMMON /OUTPUT2/ ALPHA(8,2,5),BETA(8,2,5),IJK(8,2,5),
     Z  T(8,2,5 ),R2(8,2,5)
      COMMON/GRID/BLAT(11),BLON(21),XXJ(11,21),SXXJ(11,21),
     Z      XXJ2(11,21),SXXJ2(11,21),CONG(11,21),SCONG(11,21),
     Z    CONG2(11,21),SCONG2(11,21),DXXJ(11,21),DSXXJ(11,21)
      INTEGER TSLAT, TSLON
      DIMENSION ERSO2(5),ERSUL(5)
      DIMENSION OID(5),OLAT(5),OLON(5),WIOROT(5)
      DIMENSION ICOUNT(5,2)
      COMMON/INPUT2/X(100),Y(100)
      DIMENSION  LAT(100),LON(100)
      REAL LAT,LON
      DATA PI/3.14159/
          REWIND 14
      DO 20 I=1,5
      READ(14) OID(I), OLAT(I),OLON(I),WIOROT(I),ERSO2(I),ERSUL(I)
   20 CONTINUE
       READ(14) NO, NDY, NTS, NTPDY, LTAAT, LMAAT, LBAAT
       READ(14) TSDUR, ALATT, ALONL
   40 FORMAT(3F15.5)
         REWIND 5
      DO 499 NN=1,81
      READ(5,498)          LAT(NN),LON(NN)
  498  FORMAT(2F10.2)
       WRITE(6,498)  LAT(NN),LON(NN)
  499 CONTINUE
      N=0
      DO 495 I=1,81
        ABLON=(ALATT+LAT(I))/2.
      X(I)=(ALONL-LON(I))*COS(ABLON*PI/180.)*60.
      Y(I)=(ALATT-LAT(I))*60.
      N=N+1
  495 CONTINUE
      DO 500 IO=1,NO
      WRITE(6,416) OID(IO), OLAT(IO),OLON(IO)
  416 FORMAT(1H1,A3,"(",F4.1,1X,F6.1,")")
      IF(IO.EQ.1) GO TO 1
      IF(IO.EQ.2) GO TO 2
      IF(IO.EQ.3) GO TO 3
      IF(IO.EQ.4) GO TO 4
      IF(IO.EQ.5) GO TO 5
    1 III=21
      KKK=24
      GO TO 6
    2 III=25
      KKK=28
      GO TO 6
    3 III=29
      KKK=32
      GO TO 6
    4 III=33
      KKK=36
      GO TO 6
    5 III=37
      KKK=40
    6 DO 100 I=III,KKK
      KUNIT=I
      DO 450 M=1,NDY
      DO 451 K=1,NTPDY
      ICOUNT(M,K)=0
  451 CONTINUE
  450 CONTINUE
      DO 425 M=1,NDY
          DO 422 K = 1, NTPDY
              DO 420 J = 1, NTS
                 READ (KUNIT) TSLAT(J,K,M), TSLON(J,K,M), UBAR(J,K,M),
     Z SPREAD(J,K,M), ALPHA(J,K,M), BETA(J,K,M ), T(J,K,M), R2(J,K,M),
     Z IJK(J,K,M),IALL
        IF(IALL.EQ.999) GO TO 422
      ICOUNT(M,K)=ICOUNT(M,K)+1
  420        CONTINUE
  422     CONTINUE
  425 CONTINUE
      CALL CONCAL (I,OLAT,OLON,NTS,NTPDY,NDY,TSDUR,ALATT,ALONL,LTAAT,
     Z LMAAT,LBAAT,ERSO2,ERSUL,WIOROT,IO,ICOUNT,N)
    100 CONTINUE
    500 CONTINUE
        STOP
        END


        SUBROUTINE BADGET
     Z              (REMV1,REMV2,DREMV,AVG1,AVG2,
     Z               ARAMDA1,ARAMDA2,ACONVR,AH,AUBAR,
     Z               AR2,AWOR,I,J,K,M,CSO2,CSO4,DSO2,
     Z               DSULF,PSO2,PSULF,TSULF)
C*******THIS SUBPROGRAM CALCULATES THE DEPOSITION AMOUNTS OF
C        SO2 AND SO4 DUE TO DRY AND WET DEPOSITIONS ALONG
C        TRAJECTORY AND ACCUMULATES THE VALUES FOR THE AREA
C        OVER THE ENTIRE PERIOD
        COFF=4.32*1.0E-5
C*******WHERE COEF IS THE FACTOR TO CONVERT TO (KG/12HRS)**********
         X=1852.0*AR2
        IF(M.EQ.1.AND.K.EQ.1) GO TO 1000
         IF(M.EQ.1.AND.K.EQ.2.AND.J.LE.7) GO TO 1000
         IF(M.EQ.2.AND.K.EQ.1.AND.J.LE.5) GO TO 1000
         IF(M.EQ.2.AND.K.EQ.2.AND.J.LE.3) GO TO 1000
         IF(M.EQ.2.AND.K.EQ.2.AND.J.EQ.8) GO TO 1000
         IF(M.EQ.3.AND.K.EQ.1.AND.J.EQ.1) GO TO 1000
         IF(M.EQ.3.AND.K.EQ.1.AND.J.GE.6) GO TO 1000
         IF(M.EQ.3.AND.K.EQ.2.AND.J.LE.4) GO TO 1000
         IF(M.EQ.4.AND.K.EQ.1.AND.J.GE.2) GO TO 1000
         IF(M.EQ.4.AND.K.EQ.2)            GO TO 1000
         SULD=CSO2
          SUFT=CSO4
          IJ=MOD((I-21),4)+1
          GO TO (100,200,300,400),IJ
  100     GO TO (110,130),K
  200     GO TO (210,230),K
  300     GO TO (310,330),K
  400     GO TO (410,430),K
  110      IF(J.LE.2) GO TO 111
           IF(J.LE.4) GO TO 112
           IF(J.LE.6) GO TO 113
           IF(J.LE.8) GO TO 114
  111      CSULD=SULD
           CSUFT=SUFT
           GO TO 2000
  112 CSULD=SULD
        CSUFT=SUFT
        GO TO 2000
  113      GO TO 111
  114      GO TO 112
  130     IF(J.LE.2) GO TO 112
          IF(J.LE.4) GO TO 111
          IF(J.LE.6) GO TO 112
          IF(J.LE.8) GO TO 111
  210   IF(J.LE.4) GO TO 212
        IF(J.LE.6) GO TO 211
        IF(J.LE.8) GO TO 112
  211   CSULD=SULD
        CSUFT=SUFT
        GO TO 2000
  212   CSULD=0.0
        CSUFT=0.0
        GO TO 2000
  230   IF(J.LE.2) GO TO 212
        IF(J.LE.4) GO TO 211
        IF(J.LE.6) GO TO 112
        GO TO 111
  310   GO TO 212
  330   IF(J.LE.6) GO TO 212
        GO TO 211
  410   GO TO 212
  430   IF(J.LE.6) GO TO 212
        GO TO 211
 1000   CSULD=0.0
        CSUFT=0.0
 2000   IF(REMV2.EQ.0.0) GO TO 3000
         CC=AH*AUBAR/REMV1
          DD=AH*AUBAR/REMV2
          EE=1.5*ACONVR*AH*CSULD*AWOP/DREMV
          A1=-X/CC
          B1=-X/DD
          A1=1.0-EXP(A1)
          B1=1.0-EXP(B1)
C******** CALCULATION OF DRY DEPOSITION AMOUNTS**********
          DSO21=CSULD*AWOR*CC*A1*COEF
          DSO2=DSO21*AVG1
          DSULF1=CSUFT*AWOR*DD*B1+EE*(DD*B1-CC*A1)
          DSULF1=DSULF1*COEF
          DSULF=DSULF1*AVG2
C***** WHERE DSO2 IS THE DRY DEPOSISION OF SO2 AND DSULF IS THE
C        DRY DEPOSITION OF SULFATE**************
C*****    CALCULATION OF WET DEPOSITION **************
          PSO2=DSO21*ARAMDA1
          PSULF=DSULF1*ARAMDA2
          TSULF=(DSO2+PSO2)/2.0+(DSULF+PSULF)/3.0
          KKK=1
         GO TO 3500
 3000     DSO2=0.0
          DSULF=0.0
          PSO2=0.0
          PSULF=0.0
          TSULF=0.0
          KKK=2
 3500      CONTINUE
           RETURN
           END

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          SUBROUTINE CONCAL (I,OLAT,OLON,NTS, NTPDY,NDY,TSDUR,ALATT,ALONL,
         Z LTAAT,
         Z LMAAT,LHAAT,ERSO2,ERSUL,WIORO,IO,ICOUNT,N)
 C------CALCULATE THE CONCENTRATIONS ON GRID POINTS-------------------
          COMMON /OUTPUT1/ TSLAT(8,2,5),TSLON(8,2,5),UBAR(8,2,5),
         Z  SPREAD(8,2,5)
          COMMON /OUTPUT2/ ALPHA(8,2,5),BETA(8,2,5),IJK(8,2,5),
         Z  T(8,2,5 ),R2(8,2,5)
            DIMENSION PXXJ(11,21),PSXXJ(11,21)
            DIMENSION   PSI(13,100)
            DIMENSION  PSA(13,100)
            COMMON/INPUT1/ PS(100)
            COMMON/GRID/BLAT(11),BLON(21),XXJ(11,21),SXXJ(11,21),
         Z      XXJ2(11,21),SXXJ2(11,21),CONG(11,21),SCONG(11,21),
         Z    CONG2(11,21),SCONG2(11,21),DXXJ(11,21),DSXXJ(11,21)

            INTEGER TSLAT,TSLON
            DIMENSION WOR(8,2,5),CONC(8,2,5),SCONC(8,2,5)
            DIMENSION GAMMA(11,21),C(11,21)
            DIMENSION INDEX(11,21),INDEX2(11,21)
            DIMENSION VG1(8,2,5),VG2(8,2,5)
            DIMENSION CONVR(8,2,5),H(8,2,5),RAMDA1(8,2,5),RAMDA2(8,2,5)
            DIMENSION ORCON(5),SORCON(5),WIORO(5)
            DIMENSION OLAT(5),OLON(5)
            DIMENSION ERSO2(5),ERSUL(5)
            DIMENSION ICOUNT(5,2)
            PI=3.14159
               DO 445 KK=1,81
               PSI(1,KK)=0.0
   445         CONTINUE
              REWIND 7
               DO 555 II=2,7
               DO 556 KK=1,81
               READ(7,557) PSI(II,KK)
   557         FORMAT(F4.3)
   556         CONTINUE
   555         CONTINUE
              DO 558 II=8,11
               DO 559 KK=1,81
               PSI(II,KK)=0.0
   559         CONTINUE
   558         CONTINUE
              REWIND 7
            DO 5000 M=1,NDY
            DO 4000 K=1,NTPDY
            ICC=ICOUNT(M,K)
               DO 4444 J=1,ICC,2
                DO 4555 KK=1,81
                 IF(M.EQ.1.AND.K.EQ.1)  GO TO 1111
                 IF(M.EQ.1.AND.K.EQ.2)  GO TO 1112
                 IF(M.EQ.2.AND.K.EQ.1)  GO TO 1113
                 IF(M.EQ.2.AND.K.EQ.2)  GO TO 1114
                 IF(M.EQ.3.AND.K.EQ.1)  GO TO 1115
                 IF(M.EQ.3.AND.K.EQ.2)  GO TO 1116
                 IF(M.EQ.4.AND.K.EQ.1)  GO TO 1117
                 IF(M.EQ.4.AND.K.EQ.2)  GO TO 1118
  1111      JJ=(J+1)/2
             GO TO 1121
  1112      JJ=(J+1)/2+1
            GO TO 1121
  1113      JJ=(J+1)/2+2
            GO TO 1121
  1114      JJ=(J+1)/2+3
            GO TO 1121
  1115      JJ=(J+1)/2+4
            GO TO 1121
  1116      JJ=(J+1)/2+5
            GO TO 1121
  1117      JJ=(J+1)/2+6
            GO TO 1121
  1118      JJ=(J+1)/2+7
  1121      PSA(J,KK)=PSI(JJ,KK)
            PSA(J+1,KK)=PSI(JJ,KK)
  4555      CONTINUE
  4444      CONTINUE
```

```
      DO 3000 J=1,ICC
        IF(TSLAT(J,K,M).EQ.999.OR.TSLON(J,K,M).EQ.9999)
     Z   GO TO 4000
      IF(J.EQ.1) GO TO 2999
      AX=0.5*(TSLON(J-1,K,M)/10.+TSLON(J,K,M)/10.)
      AY=0.5*(TSLAT(J-1,K,M)/10.+TSLAT(J,K,M)/10.)
          ABLON=(ALATT+AY)/2.
           AX=(ALONL-AX)*COS(ABLON*PI/180.)*60.
           AY=(ALATT-AY)*60.
      GO TO 2998
 2999 AX=0.5*(ULON(IO)+TSLON(J,K,M)/10.)
      AY=0.5*(ULAT(IO)+TSLAT(J,K,M)/10.)
          ABLON=(ALATT+AY)/2.
           AX=(ALONL-AX)*COS(ABLON*PI/180.)*60.
           AY=(ALATT-AY)*60.
 2998 CONTINUE
        DO 3995 KK=1,81
        PS(KK)=PSA(J,KK)
 3995   CONTINUE
           CALL  REMOVE (I,M,K,J,VGA,VGB,TRAR,HGT,RAMAA,RAMBB,
     Z LTAAT,LMAAT,LRAAT,AX,AY,ALATT,ALONL,N)
      VG1(J,K,M)=VGA
      VG2(J,K,M)=VGB
      CONVR(J,K,M)=TRAR
      H(J,K,M)=HGT
      RAMDA1(J,K,M)=RAMAA
      RAMDA2(J,K,M)=RAMBB
 3000 CONTINUE
        DO 3999 J=1,ICC
        DO 3998 KK=1,81
        PSA(J,KK)=0.0
         PS(KK)=0.0
 3998   CONTINUE
 3999   CONTINUE
 4000 CONTINUE
 5000 CONTINUE
      WORO=WIOHO(IO)
      DO 87 M = 1, NDY
         DO 86 K = 1, NTPDY
      ICC=ICOUNT(M,K)
            DO 85 J = 1, ICC
               WOR(J, K, M)=0.
               CONC(J, K, M)=0.
               SCONC(J, K, M)=0.
   85       CONTINUE
   86    CONTINUE
   87 CONTINUE
      IF(I.NE.21) GO TO 101
      DO 100 II=1,11
      DO 99 JJ = 1, 21
      III=II-1
      JJK=JJ-1
      BLAT(II)=ALATT-1.0*III
      BLON(JJ)=ALONL-1.0*JJK
      CONG(II,JJ)=0.0
      SCONG(II,JJ)=0.0
      CONG2(II,JJ)=0.0
      SCONG2(II,JJ)=0.0
   99 CONTINUE
  100 CONTINUE
         REWIND 50
       DO 98 II=1,11
       READ(50)  (XXJ(II,JJ),SXXJ(II,JJ),XXJ2(II,JJ),SXXJ2(II,JJ),
     1 DXXJ(II,JJ),DSXXJ(II,JJ),PXXJ(II,JJ),PSXXJ(II,JJ),JJ=1,21)
   98  CONTINUE
         REWIND 52
          READ(52) ADSO2,ADSULF,APSO2,APSULF,ATSUL
  101  CONTINUE
      DO 800 M=1,NDY
      DO 700 K=1,NTPDY
      ICC=ICOUNT(M,K)
      DO 600 J=1,ICC
        IF(TSLAT(J,K,M).EQ.999.OR.TSLON(J,K,M).EQ.9999)
     Z   GO TO 666
      REMV1=VG1(J,K,M)+RAMDA1(J,K,M)          +CONVR(J,K,M)*H(J,K,M)
      REMV2=VG2(J,K,M)+RAMDA2(J,K,M)
      DREMV=REMV1-REMV2
      VG1H=VG1(J,K,M)/H(J,K,M)
      VG2H=VG2(J,K,M)/H(J,K,M)
      DREMVH=DREMV/H(J,K,M)
      DA=EXP(-VG1H*TSDUR*3600.0)
      DB=EXP(-VG2H*TSDUR*3600.0)
      DC=EXP( DREMVH*TSDUR* 3600.0 )-1.0
      DP1=EXP( -RAMDA1(J,K,M)*TSDUR*3600.0/H(J,K,M))
      DP2=EXP( -RAMDA2(J,K,M)*TSDUR*3600.0/H(J,K,M))
      DCON=EXP( -CONVR(J,K,M)*TSDUR*3600.0 )
      SWIDTH=WORO+2.*1852.*SPREAD(J,K,M)*60.
      IF(J.NE.1) GO TO 601
      WOR(J,K,M)=WORO
        ORCON(IO)=(ERSO2(IO)/(WORO*H(1,K,M)*UBAR(1,K,M)))*31710.
         SORCON(IO)=(ERSUL(IO)/(WORO*H(1,K,M)*UBAR(1,K,M)))*31710.
      CONC(J,K,M)=((ORCON(IO)*WOR(J,K,M))/SWIDTH)*DA*DCON*DP1
      SCONC(J,K,M)= (SORCON(IO)*WOR(J,K,M)/SWIDTH)*DB*DP2
     A  +(1.5*CONVR(J,K,M)*H(J,K,M)/DREMV )*CONC(J,K,M)*DC
      GO TO 577
  601 WOR(J,K,M)=WORO+2.*60.*1852.*SPREAD(J-1,K,M)
      CONC(J,K,M)=((CONC(J-1,K,M)*WOR(J,K,M))/SWIDTH)*DA*DCON*DP1
      SCONC(J,K,M)=((SCONC(J-1,K,M)*WOR(J,K,M))/SWIDTH)*DB*DP2
     A +(1.5*CONVR(J,K,M)*H(J,K,M)/DREMV )
     A     *CONC(J,K,M)*DC
  577 WRITE(6,1001) I,TSLAT(J,K,M),TSLON(J,K,M),CONC(J,K,M),SCONC(J,K,M)
     A,M,K,J
        IF(J.EQ.1) GO TO 3333
        CS02=CONC(J-1,K,M)
        CS04=SCONC(J-1,K,M)
        GO TO 5555
 3333   CS02=ORCON(IO)
        CS04=SURCON(IO)
 5555    CALL BADGET
     Z          (REMV1,REMV2,DREMV,VG1(J,K,M),VG2(J,K,M),
     Z           RAMDA1(J,K,M),RAMDA2(J,K,M),CONVR(J,K,M),
     Z           H(J,K,M),UBAR(J,K,M),R2(J,K,M),WOR(J,K,M),
     Z           I,J,K,M,CS02,CS04,DS02,DSULF,PS02,PSULF,TSULF)
          ADS02=ADS02+DS02
          ADSULF=ADSULF+DSULF
          APSULF=APSULF+PSULF
          APS02=APS02+PS02
          ATSUL=ATSUL+TSULF
 1001 FORMAT(10X,3I10,2F20.5,3I7)
  600 CONTINUE
  666  CONTINUE
        DO 222 II=1,11
        DO 221 JJ=1,21
        INDEX(II,JJ)=0
        INDEX2(II,JJ)=0
  221   CONTINUE
  222   CONTINUE
      DO 650 J=1,ICC
        IF(TSLAT(J,K,M).EQ.999.OR.TSLON(J,K,M).EQ.9999)
     Z  GO TO 700
      WRITE(6,651) ALPHA(J,K,M),BETA(J,K,M),IJK(J,K,M),T(J,K,M)
     A,R2(J,K,M),SPREAD(J,K,M),UBAR(J,K,M),TSLAT(J,K,M),TSLON(J,K,M)
  651 FORMAT(2F10.3,I5,4F10.3,2I10)
      IF  ( J .EQ. 1) GO TO 599
      IF  (TSLAT(J, K, M)/10. .GT. BLAT(1) .AND.
     Z     TSLAT(J-1, K, M)/10. .GE. BLAT(1) .OR.
     Z     TSLAT(J, K, M)/10. .LT. BLAT(11) .AND.
     Z     TSLAT(J-1, K, M)/10. .LE. BLAT(11)) GO TO 700
      IF  (TSLON(J, K, M)/10. .GT. BLON(1) .AND.
     Z     TSLON(J-1, K, M)/10. .GE. BLON(1) .OR.
     Z     TSLON(J, K, M)/10. .LT. BLON(21) .AND.
     Z     TSLON(J-1, K, M)/10. .LE. BLON(21)) GO TO 700
  599 CONTINUE
      IF(J.EQ.1) GO TO 50
      TTLAT=TSLAT(J-1,K,M)/10.
      TTLON=TSLON(J-1,K,M)/10.
      GO TO 51
   50 TTLAT=OLAT(IO)
      TTLON=OLON(IO)
   51 CONTINUE
         DO 10 II=1,11
        DO 9 JJ=1,21
      GX=(TTLON-BLON(JJ))*60.*COS(TTLAT*PI/180.)
      GY=(BLAT(II)-TTLAT)*60.
      IF(BLON(JJ).EQ.TTLON) GO TO 5
      IF(BLAT(II).EQ.TTLAT) GO TO 6
      RATIO=ABS(GY/GX)
      GAMMA(II,JJ)=ATAN(RATIO)
      IF(BLAT(II).GE.TTLAT.AND.BLON(JJ).LE.TTLON) GO TO 21
      IF(BLAT(II).GE.TTLAT.AND.BLON(JJ).GT.TTLON) GO TO 22
      IF(BLAT(II).LT.TTLAT.AND.BLON(JJ).GT.TTLON) GO TO 23
      IF(BLAT(II).LT.TTLAT.AND.BLON(JJ).LE.TTLON) GO TO 24
   21 GAMMA(II,JJ)=GAMMA(II,JJ)
      GO TO 30
   22 GAMMA(II,JJ)=PI-GAMMA(II,JJ)
      GO TO 30
   23 GAMMA(II,JJ)=PI+GAMMA(II,JJ)
      GO TO 30
   24 GAMMA(II,JJ)=2.*PI-GAMMA(II,JJ)
      GO TO 30
    5 IF(BLAT(II).GE.TTLAT) GO TO 4
      GAMMA(II,JJ)=1.5*PI
      GO TO 30
    4 GAMMA(II,JJ)=0.5*PI
      GO TO 30
    6 IF(BLON(JJ).LE.TTLON) GO TO 7
      GAMMA(II,JJ)=PI
      GO TO 30
    7 GAMMA(II,JJ)=0.
   30 C(II,JJ)=SQRT(GX*GX+GY*GY)
    9 CONTINUE
   10 CONTINUE
      DELTA1=ALPHA(J,K,M)+0.5*PI
      DELTA2=ALPHA(J,K,M)+1.5*PI
      PHAI1=ALPHA(J,K,M)+BETA(J,K,M)
      PHAI2=ALPHA(J,K,M)-BETA(J,K,M)
        EE=T(J,K,M)*T(J,K,M)-R2(J,K,M)*R2(J,K,M)
        E=SQRT(EE)
        F=R2(J,K,M)+E
      DO 250 II=1,11
      DO 248 JJ = 1, 21
        IF(M.EQ.1.AND.K.EQ.1)       GO TO 150
         IF(M.EQ.1.AND.K.EQ.2.AND.J.LE.7) GO TO 150
         IF(M.EQ.2.AND.K.EQ.1.AND.J.LE.5) GO TO 150
         IF(M.EQ.2.AND.K.EQ.2.AND.J.LE.3) GO TO 150
         IF(M.EQ.2.AND.K.EQ.2.AND.J.GE.8) GO TO 150
         IF(M.EQ.3.AND.K.EQ.1.AND.J.EQ.1) GO TO 150
         IF(M.EQ.3.AND.K.EQ.1.AND.J.GE.6) GO TO 150
         IF(M.EQ.3.AND.K.EQ.2.AND.J.GE.4) GO TO 150
         IF(M.EQ.4.AND.K.EQ.1.AND.J.GE.2) GO TO 150
         IF(M.EQ.4.AND.K.EQ.2)            GO TO 150
      IF(J.EQ.1.AND.BLAT(II).EQ.OLAT(IO).AND.BLON(JJ).EQ.OLON(IO))
     A       GO TO 350
      IF(J.EQ.1.AND.C(II,JJ).LE.WORO/(2.*1852.) .AND.GAMMA(II,JJ).EQ.
     A    DELTA1.OR.GAMMA(II,JJ).EQ.DELTA2) GO TO 350
      IF(C(II, JJ) .GT. F) GO TO 150
      IF(IJK(J,K,M).EQ.1) GO TO 110
      IF(IJK(J,K,M).EQ.2) GO TO 120
      IF(IJK(J,K,M).EQ.3) GO TO 120
      IF(IJK(J,K,M).EQ.4) GO TO 130
      IF(IJK(J,K,M).EQ.5) GO TO 140
  110 IF(BETA(J,K,M).LT.ALPHA(J,K,M)) GO TO 111
      IF(GAMMA(II,JJ).GE.ALPHA(J,K,M).AND.GAMMA(II,JJ).LE.PHAI1.OR.
     A   GAMMA(II,JJ).GE.(2.*PI+PHAI2).AND.GAMMA(II,JJ).LE.2.*PI.OR.
     A   GAMMA(II,JJ).GT.0. .AND.GAMMA(II,JJ).LT.ALPHA(J,K,M))
     A   GO TO 112
      GO TO 113
  112 D1=R2(J,K,M)/COS(ALPHA(J,K,M)-GAMMA(II,JJ))
      D1=ABS(D1)
      IF(C(II,JJ).LE.D1) GO TO 165
      GO TO 149
  111 IF(GAMMA(II,JJ).GE.PHAI2.AND.GAMMA(II,JJ).LE.PHAI1) GO TO 112
      GO TO 114
  113 IF(GAMMA(II,JJ).GT.PHAI1.AND.GAMMA(II,JJ).LE.DELTA1)  GO TO 170
      IF(GAMMA(II,JJ).GE.DELTA2.AND.GAMMA(II,JJ).LT.(2.*PI+PHAI2))
     A GO TO 170
      GO TO 150
  114 IF(GAMMA(II,JJ).GT.PHAI1.AND.GAMMA(II,JJ).LE.DELTA1) GO TO 170
      IF(GAMMA(II,JJ).GE.DELTA2.AND.GAMMA(II,JJ).LT.2.*PI.OR.
     A   GAMMA(II,JJ).GE.0. .AND.GAMMA(II,JJ).LT.PHAI2)  GO TO 170
      GO TO 150
  120 IF(GAMMA(II,JJ).GE.PHAI2.AND.GAMMA(II,JJ).LE.PHAI1) GO TO 112
      DELTA2=DELTA2-2.*PI
      IF(GAMMA(II,JJ).GE.DELTA2.AND.GAMMA(II,JJ).LT.PHAI2.OR.
     A   GAMMA(II,JJ).GT.PHAI1.AND.GAMMA(II,JJ).LE.DELTA1) GO TO 170
      GO TO  150
  130 DELTA1=DELTA1-2.*PI
      DELTA2=DELTA1+PI
      IF(PHAI1.LT.2.*PI) GO TO 131
      IF(GAMMA(II,JJ).GE.PHAI2.AND.GAMMA(II,JJ).LE.2.*PI.OR.
     A   GAMMA(II,JJ).GT.0..AND.GAMMA(II,JJ).LE.(PHAI1-2.*PI)) GO TO 112
      IF(GAMMA(II,JJ).LE.DELTA1.AND.GAMMA(II,JJ).GT.(PHAI1-2.*PI))
     A        GO TO 170
      IF(GAMMA(II,JJ).GE.DELTA2.AND.GAMMA(II,JJ).LT.PHAI2) GO TO 170
      GO TO 150
  131 IF(GAMMA(II,JJ).GE.PHAI2.AND.GAMMA(II,JJ).LE.PHAI1) GO TO 112
      IF(GAMMA(II,JJ).GE.DELTA2.AND.GAMMA(II,JJ).LT.PHAI2)  GO TO 170
      IF(GAMMA(II,JJ).GT.PHAI1.AND.GAMMA(II,JJ).LE.2.*PI.OR.
     A   GAMMA(II,JJ).GT.0..AND.GAMMA(II,JJ).LE.DELTA1)  GO TO 170
      GO TO 150
  170 ANGLE=ABS(GAMMA(II,JJ)-ALPHA(J,K,M))
      CDX=C(II,JJ)*COS(ANGLE)
      DDX=C(II,JJ)*SIN(ANGLE)
      CDX=ABS(CDX)
      DDX=ABS(DDX)
      IF(J.EQ.1) GO TO 175
      WIDTH=WORO/(2.*1852.)+(SPREAD(J-1,K,M)+CDX*(SPREAD(J,K,M)-
     ASPREAD(J-1,K,M)) /R2(J,K,M))*60.
      IF(DDX.GT.WIDTH) GO TO 150
      GO TO 160
  175 WIDTH=WORO/(2.*1852.)+CDX*(SPREAD(J,K,M)*60.-WORO/(2.*1852.))
     A /R2(J,K,M)
      IF(DDX.GT.WIDTH) GO TO 150
      GO TO 160
  149 AA=C(II,JJ)*C(II,JJ)+R2(J,K,M)*R2(J,K,M)-2.*C(II,JJ)*R2(J,K,M)
     A *COS(ALPHA(J,K,M)-GAMMA(II,JJ))
      A=SQRT(AA)
      IF(A.LE.E) GO TO 162
  150 CONG(II,JJ)=0.0
      SCONG(II,JJ)=0.0
      CONG2(II,JJ)=0.0
      SCONG2(II,JJ)=0.0
      INDEX(II,JJ)=1
      GO TO 249
  165 CDX=C(II,JJ)*COS(GAMMA(II,JJ)-ALPHA(J,K,M))
      CDX=ABS(CDX)
  160 CONTINUE
```

```
       IF(CDX.GE.R2(J,K,M)) GO TO 150
      REMV1=VG1(J,K,M)+RAMDA1(J,K,M)          +CONVR(J,K,M)*H(J,K,M)
      REMV2=VG2(J,K,M)+RAMDA2(J,K,M)
      DREMV=REMV1-REMV2
      DREMVH=DREMV/H(J,K,M)
      VG1H=VG1(J,K,M)/H(J,K,M)
      VG2H=VG2(J,K,M)/H(J,K,M)
      D4=EXP(-VG1H*CDX*1852./UBAR(J,K,M))
      D5=EXP(-VG2H*CDX*1852./UBAR(J,K,M))
      D6=EXP(DREMVH*CDX*1852./UBAR(J,K,M))-1.
      D7=EXP(-CONVR(J,K,M)*CDX*1852./UBAR(J,K,M))
      DP4=EXP(-RAMDA1(J,K,M)*CDX*1852./UBAR(J,K,M)/H(J,K,M))
      DP5=EXP(-RAMDA2(J,K,M)*CDX*1852./UBAR(J,K,M)/H(J,K,M))
      IF(UBAR(J,K,M).EQ.0.0) GC TO 140
      IF(R2(J,K,M).EQ.0.0) GO TO 140
      IF(J.EQ.1) GO TO 161
      SIGH=2.*60.*1852.*(SPREAD(J-1,K,M)+(CDX/R2(J,K,M))*(SPREAD(J,K,M)
     A   -SPREAD(J-1,K,M)))
      CONG(II,JJ)=((CONC(J-1,K,M)*WOR(J-1,K,M))/(WORO+SIGH))*D4*D7*DP4
      SCONG(II,JJ)=((SCONC(J-1,K,M)*WOR(J-1,K,M))/(WORO+SIGH))*D5*DP5
     A  +(1.5*CONVR(J,K,M)*H(J,K,M)/DREMV)
     A   *CONC(J,K,M)*D6
      INDEX(II,JJ)=2
      GO TO 249
  161 SIGH=(2.*60.*1852.*SPREAD(J,K,M)*CDX/R2(J,K,M))
      CONG(II,JJ)=((ORCON(IO)*WORO)/(WORO+SIGH))*D4*D7*DP4
      SCONG(II,JJ)=((SORCON(IO)*WORO)/(WORO+SIGH))*D5*DP5
     A     +(1.5*CONVR(J,K,M)*H(J,K,M)/DREMV)*CONC(J,K,M)*D6
      INDEX(II,JJ)=2
      GO TO 249
  350 CONG(II,JJ)=ORCON(IO)
      SCONG(II,JJ)=SORCON(IO)
      INDEX(II,JJ)=2
      GO TO 249
  162 CONG(II,JJ)=CONC(J,K,M)
      SCONG(II,JJ)=SCONC(J,K,M)
      INDEX(II,JJ)=2
      GO TO 249
  140 CONG(II,JJ)=0.
      SCONG(II,JJ)=0.0
      INDEX(II,JJ)=1
  249 IF(INDEX2(II,JJ).EQ.2.AND.INDEX(II,JJ).EQ.2) GO TO 251
      GO TO 252
  251 CONG(II,JJ)=0.0
      SCONG(II,JJ)=0.0
  252 SULD=CONG(II,JJ)
      SUFT=SCONG(II,JJ)
      SULD2=CONG(II,JJ)
      SUFT2=SCONG(II,JJ)
      CALL   DETCON(I,J,K,SULD,SUFT,SULD2,SUFT2,CSULD,CSUFT,CSULD2,
     Z CSUFT2 )
      XXJ(II,JJ)=XXJ(II,JJ)+CSULD
      SXXJ(II,JJ)=SXXJ(II,JJ)+CSUFT
      XXJ2(II,JJ)=XXJ2(II,JJ)+CSULD2
      SXXJ2(II,JJ)=SXXJ2(II,JJ)+CSUFT2
      DCONG=CSULD*(VG1(J,K,M)+RAMDA1(J,K,M))*3.6*12.0
      DSCONG=CSUFT*(VG2(J,K,M)+RAMDA2(J,K,M))*3.6*12.0
      DXXJ(II,JJ)=DXXJ(II,JJ)+DCONG
      DSXXJ(II,JJ)=DSXXJ(II,JJ)+DSCONG
         PSO=CSULD*RAMDA1(J,K,M)*3.6*12.0
          PSUL=CSUFT*RAMDA2(J,K,M)*3.6*12.0
          PXXJ(II,JJ)=PXXJ(II,JJ)+PSO
          PSXXJ(II,JJ)=PSXXJ(II,JJ)+PSUL
C*****WHERE PXXJ AND PSXXJ ARE RESPECTIVELY DEPOSISION AMOUNTS OF SO2
C     AND SULFATE DUE TO RAIN****************
      INDEX2(II,JJ)=INDEX(II,JJ)
  248 CONTINUE
  250 CONTINUE
      DO 661 II=1,11
      DO 660 JJ = 1, 21
      CONG(II,JJ)=0.0
      SCONG(II,JJ)=0.0
      CONG2(II,JJ)=0.0
      SCONG2(II,JJ)=0.0
      GAMMA(II,JJ)=0.0
      C(II,JJ)=0.0
  660 CONTINUE
  661 CONTINUE
  650 CONTINUE
  700 CONTINUE
  800 CONTINUE
          REWIND 51
       DO 795 II=1,11
        WRITE(51) BLAT(II)
  795   CONTINUE
        DO 796 JJ=1,21
        WRITE(51) BLON(JJ)
  796   CONTINUE
          REWIND 50
      DO 802 II=1,11
       WRITE(50) (XXJ(II,JJ),SXXJ(II,JJ),XXJ2(II,JJ),SXXJ2(II,JJ),
     1 DXXJ(II,JJ),DSXXJ(II,JJ),PXXJ(II,JJ),PSXXJ(II,JJ),JJ=1,21)
  802  CONTINUE
```

```
      REWIND 52
       WRITE(52) ADSO2,ADSULF,APSO2,APSULF,ATSUL
      RETURN
      END


      SUBROUTINE  CONHUL (X,Y,NPTS,IP,IP2,IER)
      COMMON/TRIAN1/I1,NP,XSCALE,YSCALE,XMIN,YMIN,XMAX,YMAX,NL,NT
      LOGICAL  EQUAL ,START,LAB
      DIMENSION  X(81),Y(81),IP(1),IP2(1)
      IER=0
      START=.TRUE.
      NP=NPTS
      IF(NP.LT.4) GO TO 112
      EQUAL=.FALSE.
      CALL SORT1 (IP,IP2,NPTS,LAB,I1,J,MTEST)
  101 CALL SORT2 (IP,IP2,NPTS,LAB,I1,J,MTEST)
      IF(LAB) GO TO 106
      IF(X(I1)-X(J)) 104,102,105
  102 IF  (Y(I1)-Y(J)) 105,103,104
  103 EQUAL=.TRUE.
      MTEST=0
      GO TO 101
  104 MTEST=-1
      GO TO 101
  105 MTEST=+1
      GO TO 101
  106 IH=I1
      IF(.NOT.EQUAL) GO TO 111
      DO 107 ITAIL=1,NPTS
      IF(IP(ITAIL).EQ.0) GO TO 108
  107 CONTINUE
  108 CONTINUE
  109 I2=IP(I1)
      IF( I2.EQ.0)  GO TO 111
      IF(Y(I1).EQ. Y(I2).AND.X(I1).EQ.X(I2)) GO TO 110
      I1=I2
      GO TO 109
  110 NP=NP-1
      IER=1
      WRITE(6,1500)
 1500 FORMAT(1X,*IER=1*)
      IP(I1)=IP(I2)
      IP(I2)=0
      IP(ITAIL)=I2
      ITAIL=I2
      GO TO 109
  111 CALL PVEC(IP,IH)
      IF(NP.GE.4) GO TO 113
  112 CONTINUE
      IER=32
      WRITE(6,1501)
 1501 FORMAT(1X,*IER=32*)
      RETURN
  113 I=IP(1)
      XMIN=X(I)
      I=IP(NP)
      XMAX=X(I)
      YMIN=Y(1)
      YMAX=Y(1)
      DO 114 I=2,NPTS
      YMAX=AMAX1(YMAX,Y(I))
      YMIN=AMIN1(YMIN,Y(I))
  114 CONTINUE
      DX=XMAX-XMIN
      DY=YMAX-YMIN
      IF(DX.NE.0. .AND. DY.NE.0.) GO TO 115
      IER=33
      WRITE(6,1502)
 1502 FORMAT(1X,*IER=33*)
      RETURN
  115 XSCALE=.707/DX
      YSCALE=.707/DX
      DO 116 I=2,NP
      J=IP(I)
      IF(X(J).NE.XMIN) GO TO 117
  116 CONTINUE
      IER=34
      WRITE(6,1503)
 1503 FORMAT(1X,*IER=34*)
      RETURN
  117 I1=I-1
  118 I2=I1+1
      I3=I1+2
      J1=IP(I1)
  119 J2=IP(I2)
      J3=IP(I3)
      DX2=XSCALE*(X(J2)-X(J1))
      DY2=YSCALE*(Y(J2)-Y(J1))
      DX3=XSCALE*(X(J3)-X(J1))
      DY3=YSCALE*(Y(J3)-Y(J1))
      IF  (DX2*DY3-DX3*DY2) 121,120,122
 120 IF(ABS(DX2)+ABS(DY2)-ABS(DX3)-ABS(DY3)) 122,122,121
 121 IP(I2)=J3
     IP(I3)=J2
 122 I3=I3+1
     IF(I3.LE.NP) GO TO 119
     IF(IP(I2).EQ.IP(1)) GO TO 124
     I1=I1+1
     IF(.NOT.START.OR.I1.LT.3) GO TO 123
     START=.FALSE.
     IP(NPTS+1)=IP(NP+1)
     IP(NP+1)=IP(1)
     NP=NP+1
 123 IF(NP-I1.GE.2) GO TO 118
     IER=35
     WRITE(6,1504)
1504 FORMAT(1X,*IER=35*)
     RETURN
 124 CONTINUE
     RETURN
     END


     SUBROUTINE DETCON (I,J,K,SULD,SUFT,SULD2,SUFT2,CSULD,CSUFT,CSULD2,
    Z CSUFT2)
       IJ=MOD((I-21),4)+1
       GO TO (100,200,300,400),IJ
 100 IF(K.EQ.1 ) GO TO 110
     IF(K.EQ.2 ) GO TO 130
 200 IF(K.EQ.1 ) GO TO 210
     IF(K.EQ. 2) GO TO 230
 300 IF(K.EQ. 1) GO TO 310
     IF(K.EQ. 2) GO TO 330
 400 IF(K.EQ. 1) GO TO 410
     IF(K.EQ. 2) GO TO 430
 110 IF(J.LE. 2) GO TO 111
     IF(J.LE. 4) GO TO 112
     IF(J.LE. 6 ) GO TO 113
     IF(J.LE. 8 ) GO TO 114
 111 CSULD=SULD
     CSUFT=SUFT
     CSULD2=0.0
     CSUFT2=0.0
     RETURN
 112 CSULD=SULD
     CSUFT=SUFT
     CSULD2=SULD2
     CSUFT2=SUFT2
     RETURN
 113 GO TO 111
 114 GO TO 112
 130 IF(J.LE.2) GO TO 112
     IF(J.LE. 4) GO TO 111
     IF(J.LE.6 ) GO TO 112
     IF(J.LE.8 ) GO TO 111
 210 IF(J.LE.  4 ) GO TO 212
     IF(J.LE. 6 ) GO TO 211
     IF(J.LE. 8 ) GO TO 112
 211 CSULD=0.0
     CSUFT=0.0
     CSULD2=SULD2
     CSUFT2=SUFT2
     RETURN
 212 CSULD=0.0
     CSUFT=0.0
     CSULD2=0.0
     CSUFT2=0.0
     RETURN
 230 IF(J.LE.2) GO TO 212
     IF(J.LE.4) GO TO 211
     IF(J.LE. 6 ) GO TO 112
     GO TO 111
 310 GO TO 212
 330 IF(J.LE.6 ) GO TO 212
     GO TO 211
 410 GO TO 212
 430 IF(J.LE. 6 ) GO TO 212
     GO TO 211
     END


     SUBROUTINE PRECIP(AX,AY,ALATT,ALONL, RAMAA,RAMBB, N)
      DIMENSION ITRI(2000)
     COMMON /INPUT1/ PS(100)
     COMMON /INPUT2/ X(100),Y(100)
     DATA PI/3.14159/
      ISUP=2000
     CALL TRIANG(X,Y,N,ITRI,ISUP,IUSED,IER)
     F1=TRINTR(AX,AY,X,Y,PS,N,ITRI)
     RAMAA=F1
     RAMBB=F1
     RETURN
     END
```

```
      SUBROUTINE PVEC (LIST,HEAD)
      DIMENSION LIST(1)
      INTEGER  HEAD
      N=0
      I=HEAD
  101 IF(I.EQ.0) GO TO 102
      N=N+1
      J=LIST(I)
      LIST(I)=N
      I=J
      GO TO 101
  102 IF(N.EQ.0) RETURN
      J=N
      K=LIST(J)
      IF(K.EQ. N) GO TO 105
  103 I=LIST(J)
      IF(I.GT.0) GO TO 104
      LIST(J)=-I
      GO TO 105
  104 LIST(J)=-K
      K=J
      J=I
      IF(J.NE.N) GO TO 103
      LIST(N)=K
  105 N=N-1
      GO TO 102
      END


      SUBROUTINE REMOVE(I,M,K,J,VGA,VGB,TRAR,HGT,RAMAA,RAMBB,
     Z LTAAT,LMAAT,LBAAT,AX,AY,ALATT,ALONL,N)
        IJ=MOD((I-21),4)+1
         GO TO (100,200,300,400),IJ
  100 IF(K.EQ.1) GO TO 110
      IF(K.EQ.2) GO TO 130
  200 IF(K.EQ.1 ) GO TO 210
      IF(K.EQ.2 ) GO TO 230
  300 IF(K.EQ.1 ) GO TO 310
      IF(K.EQ.2 ) GO TO 330
  400 IF(K.EQ.1) GO TO 410
      IF(K.EQ.2) GO TO 430
  110 IF(J.LE.2) GO TO 111
      IF(J.LE.4) GO TO 112
      IF(J.LE.6 ) GO TO 113
      GO TO 114
  130 IF(J.LE.2) GO TO 131
      IF(J.LE.4) GO TO 132
      IF(J.LE.6 ) GO TO  133
      GO TO 134
  210 IF(J.LE.2) GO TO 211
      IF(J.LE.4) GO TO 212
      IF(J.LE.6 ) GO TO 213
      GO TO 214
  230 IF(J.LE.2) GO TO 231
      IF(J.LE.4) GO TO 232
      IF(J.LE.6 ) GO TO  233
      GO TO 234
  310 IF(J.LE.2) GO TO 311
      IF(J.LE.4) GO TO 312
      IF(J.LE.6 ) GO TO 313
      GO TO 314
  330 IF(J.LE.2) GO TO 331
      IF(J.LE.4) GO TO 332
      IF(J.LE.6 ) GO TO  333
      GO TO 334
  410 IF(J.LE.2) GO TO 411
      IF(J.LE.4) GO TO 412
      IF(J.LE.6 ) GO TO 413
      GO TO 414
  430 IF(J.LE.2) GO TO 431
      IF(J.LE.4) GO TO 432
      IF(J.LE.6 ) GO TO  433
      GO TO 434
  111 VGA=0.02
      VGB=0.004
      CALL PRECIP(AX,AY,ALATT,ALONL,RAMAA,RAMBB, N)
      HGT=FLOAT(LMAAT)
       RAMBB=RAMBB*0.01*1.0E5/3600.
      RAMAA=RAMAA*0.01*1.0E5/3600.
        TRAR=0.01*(1./3600.)
      RETURN
  112 VGA=0.02
      VGB=0.004
      HGT=FLOAT(LTAAT)
      CALL PRECIP(AX,AY,ALATT,ALONL,RAMAA,RAMBB, N)
        RAMBB=RAMBB*0.01*1.0E5/3600.
       RAMAA=RAMAA*0.01*1.0E5/3600.
        TRAR=0.1*(1./3600.)
      RETURN
  113 GO TO 111
  114 GO TO 112
  131 GO TO 112
```

```
132 GO TO 111
133 GO TO 112
134 GO TO 111
211 GO TO 111
212 GO TO 112
213 VGA=0.0
    VGB=0.0
    HGT=FLOAT(LTAAT-LMAAT)
     CALL PRECIP(AX,AY,ALATT,ALONL,RAMAA,RAMBB, N)
     RAMAA=RAMAA*0.01*1.0E5/3600.
     RAMBB=RAMBB*0.01*1.0E5/3600.
      TRAR=0.01*(1./3600.)
    RETURN
214 GO TO 112
231 GO TO 112
232 GO TO 213
233 GO TO 112
234 GO TO 111
311 GO TO 111
312 GO TO 112
313 GO TO 111
314 GO TO 112
331 GO TO 112
332 GO TO 111
333 GO TO 112
334 GO TO 213
411 GO TO 111
412 GO TO 112
413 GO TO 111
414 GO TO 112
431 GO TO 112
432 GO TO 213
433 GO TO 112
434 GO TO 213
    END


    SUBROUTINE SORT1 (LIST,IHEAD,N,LAB,L1,L2,ITEST)
    DIMENSION IHEAD(N),LIST(N)
    INTEGER  DIRECT
    LOGICAL  LAB
    ASSIGN 101 TO NEXT
    LAB=.FALSE.
    RETURN
    ENTRY SORT2
    GO TO NEXT,(101,103,121)
101 CONTINUE
    M=1
    DIRECT=0
    I=1
    JHEAD=1
    LIST(1)=0
    IHEAD(1)=0
102 IF(I.GE.N) GO TO 114
    I1=I+1
    L1=I
    L2=I1
    ASSIGN 103 TO NEXT
    RETURN
103 IF(ITEST) 105,104,111
104 IF(DIRECT) 113,106,107
105 IF(DIRECT) 110,106,107
106 DIRECT=1
    JHEAD=I
107 LIST(I)=I1
    IHEAD(I)=0
108 I=I1
    GO TO 102
109 LIST(I)=0
    IHEAD(I)=0
110 IHEAD(M)=JHEAD
    M=M+1
    DIRECT=0
    GO TO 108
111 IF (DIRECT) 113,112,109
112 DIRECT=-1
    LIST(I)=0
    IHEAD(I)=0
113 LIST(I1)=I
    IHEAD(I1)=0
    JHEAD=I1
    GO TO 108
114 IHEAD(M)=JHEAD
    IF(DIRECT.LT.0) GO TO 115
    LIST(I)=0
    IHEAD(I)=0
    IF(DIRECT.EQ.0) IHEAD(M)=N
115 I=-1
    MP=0
116 I=I+2
    IF(I.LT.M) GO TO 119
    IF(I.EQ.M) GO TO 118
```

```
 117  M=MP
      IF(M.NE.1) GO TO 115
      L1=IHEAD(1)
      IHEAD(1)=0
      LAB=.TRUE.
      RETURN
 118  MP=MP+1
      IHEAD(MP)=IHEAD(1)
      IF(I.EQ.1) GO TO 117
      IHEAD(I)=0
      GO TO 117
 119  J1=IHEAD(I)
      J2=IHEAD(I+1)
      IHEAD(I)=0
      IHEAD(I+1)=0
      I1=J1
      I2=J2
      MP=MP+1
      NCHAIN=0
 120  L1=J1
      L2=J2
      ASSIGN 121 TO NEXT
      RETURN
 121  IF(ITEST.LE.0) GO TO 122
      IF(NCHAIN.EQ. 0) IHEAD(MP)=J2
      IF(NCHAIN.EQ.1) LIST(I1)=J2
      NCHAIN=2
      I2=J2

      J2=LIST(I2)
      IF(J2.NE.0) GO TO 120
      LIST(I2)=J1
      GO TO 116
 122  IF(NCHAIN.EQ.0) IHEAD(MP)=J1
      IF(NCHAIN.EQ.2) LIST(I2)=J1
      NCHAIN=1
      I1=J1
      J1=LIST(I1)
      IF(J1.NE.0) GO TO 120
      LIST(I1)=J2
      GO TO 116
      END


      SUBROUTINE STEST (X,Y,LINE,ITRI,LL,FLIP)
      COMMON/TRIAN1/ I1,NP,XSCALE,YSCALE,XMIN,YMIN,XMAX,YMAX,NL,NT
      COMMON/TRIAN2/ L2,L3, L4,L5
      DIMENSION X(1),Y(1),LINE(5,1),ITRI(3,1),E(5),INEXT(3)
      LOGICAL FLIP
      DATA INEXT/2,3,1/
      DATA FAC/1.E13/
      DATA FACI/1.E-13/
      DX(I,J)=XSCALE*(X(J)-X(I))
      DY(I,J)=YSCALE*(Y(J)-Y(I))
      EL(I)=FACI*FLOAT(IABS(LINE(5,I)))
      L1=IABS(LL)
      KT1=LINE(3,L1)
      KT2=LINE(4,L1)
      FLIP=.FALSE.
      IF(KT1.EQ.0.OR.KT2.EQ.0) RETURN
      J1=LINE(1,L1)
      J2=LINE(2,L1)
      DO 101 I=2,3
      IF(IABS(ITRI(I-1,KT1)).EC.L1) GO TO 102
 101  CONTINUE
      I=1
 102  L2=ITRI(I,KT1)
      I=INEXT(I)
      L3=ITRI(I,KT1)
      IF(L2.LT.0) GO TO 103
      J3=LINE(2,L2)
      GO TO 104
 103  L=-L2
      J3=LINE(1,L)
 104  DO 105 I=2,3
      IF(IABS(ITRI(I-1,KT2)).EQ.L1) GO TO 106
 105  CONTINUE
      I=1
 106  L4=ITRI(I,KT2)
      I=INEXT(I)
      L5=ITRI(I,KT2)
      IF(L4.LT.0) GO TO 107
      J4=LINE(2,L4)
      GO TO 108
 107  L=-L4
      J4=LINE(1,L)
 108  DX43=DX(J4,J3)
      DY43=DY(J4,J3)
      A1=DX43*DY(J4,J1)-DY43*DX(J4,J1)
      IF(A1.LE.0.) RETURN
      A2=DX(J4,J2)*DY43-DY(J4,J2)*DX43
      IF(A2.LE.0.)  RETURN
      E43=SQRT(DX43**2+DY43**2)
      E(1)=EL(L1)
      LL2=IABS(L2)
      E(2)=EL(LL2)
      E(3)=EL(IABS(L3))
      LL4=IABS(L4)
      E(4)=EL(LL4)
      E(5)=EL(IABS(L5))
      S1=A1/(E43*AMAX1(E(3),E(4)))
      S2=A2/(E43*AMAX1(F(2),E(5)))
      DX12=DX(J1,J2)
      DY12=DY(J1,J2)
      S3=(DX12*DY(J1.J3)-DY12*DX(J1,J3))/(E(1)*AMAX1(E(2),E(3)))
      S4=(DX(J1,J4)*DY12-DY(J1,J4)*DX12)/(E(1)*AMAX1(E(4),E(5)))
      IF(AMIN1(S3,S4) .GE.AMIN1(S1,S2)) RETURN
      LINE(1,L1)=J4
      LINE(2,L1)=J3
      LINE(3,L1)=KT1
      LINE(4,L1)=KT2
      LINE(5,L1)=E43*FAC
      I=3
      IF(L2.LT. 0) I=4
      LINE(I.LL2)=KT2
      I=3
      IF(L4.LT.0) I=4
      LINE(I,LL4)=KT1
      ITRI(1,KT1)=L1
      ITRI(2,KT1)=L3
      ITRI(3,KT1)=L4
      ITRI(1,KT2)=-L1
      ITRI(2,KT2)=L5
      ITRI(3,KT2)=L2
      FLIP=.TRUE.
      RETURN
      END
      FUNCTION LTEST (SX,SY,DX,DY)
      DATA TOL/1.E-13/
      T=SX*DY-DX*SY

      IF (T.GT. TOL) GO TO 105
      IF (T.LT.-TOL ) GO TO 103
      IF(ABS(SY) .GT. ABS(SX)) GO TO 101
      R=DX/DY
      GO TO 102
  101 R=DY/SY
  102 IF(0..LE.R .AND. R.LE.1.) GO TO 104
  103 LTEST=-1
      RETURN
  104 LTEST=0
      RETURN
  105 LTEST=1
      RETURN
      END


      SUBROUTINE TMESH (X,Y,NPTS,IP,LINE,ITRI,IER)
      COMMON/TRIAN1/ I1,NP,XSCALE,YSCALE,XMIN,YMIN,XMAX,YMAX,NL,NT
      DIMENSION X(NPTS),Y(NPTS),IP(1),LINE(5,1),ITRI(3,1)
      LOGICAL FLIP1,FLIP2
      DATA FAC/1.E13/
      IER=0
      K1=I1+2
      XMEAN=0.
      YMEAN=0.
      DO 101 I=K1,NP
      J=IP(I)
      XMEAN=XMEAN+X(J)
      YMEAN=YMEAN+Y(J)
  101 CONTINUE
      T=NP-K1+1
      XMEAN=XMEAN/T
      YMEAN=YMEAN/T
      T=10.
      DO 102 I=K1,NP
      J=IP(I)
      D=XSCALE*ABS(X(J)-XMEAN)+YSCALE*ABS(Y(J)-YMEAN)
      IF(D.GE.T) GO TO 102
      T=D
      IMIN=I
  102 CONTINUE
      JC=IP(IMIN)
      IP(IMIN)=IP(K1)
      IP(K1)=JC
      NT=I1
      NL=2*NT
      DO 103 I=1,NT
      LINE(1,I)=IP(I)
      LINE(2,I)=IP(I+1)
      LINE(3,I)=I
      LINE(4,I)=0
      LINE(1,I+I1)=IP(I+1)
      LINE(2,I+I1)=JC
      LINE(3,I+I1)=I
      LINE(4,I+I1)=I+1
      IF(I.EQ.I1) LINE(4,I+I1)=I
      ITRI(1,I)=I
      ITRI(2,I)=I+I1
      ITRI(3,I)=-(I+I1-1)
      IF(I.EQ.1) ITRI(3,I)=-NL
  103 CONTINUE
      DO 104 I=1,NL
      J1=LINE(1,I)
      J2=LINE(2,I)
      LINE(5,I)=FAC*
     1         SQRT((XSCALE*(X(J1)-X(J2)))**2+(YSCALE*(Y(J1)-Y(J2
     2   )))**2)
  104 CONTINUE
      I1P1=I1+1
      DO 105 L=I1P1,NL
      CALL STEST (X,Y,LINE,ITRI,L,FLIP1)
  105 CONTINUE
      K1=K1+1
      IF(K1.GT. NP) GO TO 142
      DO 141 K=K1,NP
      J=IP(K)
      DO 113 KT=1,NT
      L1=ITRI(1,KT)
      IF  (L1.LT. 0) GO TO 106
      J1=LINE(1,L1)
      J2=LINE(2,L1)
      GO TO 107
  106 L=-L1
      J1=LINE(2,L)
      J2=LINE(1,L)
  107 DX1=XSCALE*(X(J)-X(J1))
      DY1=YSCALE*(Y(J)-Y(J1))
      SX1=XSCALE*(X(J2)-X(J1))

      SY1=YSCALE*(Y(J2)-Y(J1))
      LT=LTEST(SX1,SY1,DX1,DY1)
      IF(LT) 113,108,109
  108 L2=ITRI(2,KT)
      IF(L2.LT.0) GO TO 109
      J3=LINE(2,L2)
      GO TO 110
  109 L=-L2
      J3=LINE(1,L)
  110 IF(LT) 113,114,111
  111 SX2=XSCALE*(X(J3)-X(J2))
      SY2=YSCALE*(Y(J3)-Y(J2))
      DX2=DX1-SX1
      DY2=DY1-SY1
      IF(LTEST(SX2,SY2,DX2,DY2)) 113,120,112
  112 SX3=-(SX1+SX2)
      SY3=-(SY1+SY2)
      DX3=SX3+DX1
      DY3=SY3+DY1
      IF(LTEST(SX3,SY3,DX3,DY3)) 113,121,114
  113 CONTINUE
      IER=36
      WRITE(6,1510)
 1510 FORMAT(1X,*IER=36*)
      RETURN
  114 LINE(1,NL+1)=J1
      LINE(2,NL+1)=J
      LINE(3,NL+1)=NT+2
      LINE(4,NL+1)=KT
      LINE(5,NL+1)=FAC*SQRT(DX1**2+DY1**2)
      LINE(1,NL+2)=J2
      LINE(2,NL+2)=J
      LINE(3,NL+2)=KT
      LINE(4,NL+2)=NT+1
      LINE(5,NL+2)=FAC*SQRT(DX2**2+DY2**2)
      LINE(1,NL+3)=J3
       LINE(2,NL+3)=J
      LINE(3,NL+3)=NT+1
      LINE(4,NL+3)=NT+2
      LINE(5,NL+3)=FAC*SQRT(DX3**2+DY3**2)
      IF(L2.LT. 0) GO TO 115
      LINE(3,L2)=NT+1
      GO TO 116
  115 L=-L2
      LINE(4,L)=NT+1
  116 L3=ITRI(3,KT)
      IF(L3.LT.0) GO TO 117
      LINE(3,L3)=NT+2
      GO TO 118
  117 L=-L3
      LINE(4,L)=NT+2
  118 CONTINUE
      ITRI(2,KT)=NL+2
      ITRI(3,KT)=-(NL+1)
      ITRI(1,NT+1)=L2
      ITRI(2,NT+1)=NL+3
      ITRI(3,NT+1)=-(NL+2)
      ITRI(1,NT+2)=L3
      ITRI(2,NT+2)=NL+1
      ITRI(3,NT+2)=-(NL+3)
      CALL STEST(X,Y,LINE,ITRI,L1,FLIP1)
      CALL STEST(X,Y,LINE,ITRI,L2,FLIP1)
      CALL STEST(X,Y,LINE,ITRI,L3,FLIP1)
      GO TO 140
  119 L3=ITRI(3,KT)
      GO TO 122
  120 L3=L1
      L1=L2
      L2=ITRI(3,KT)
      JT=J3
      J3=J1
      J1=J2
      J2=JT
      GO TO 122
  121 L3=L2
      L2=L1
      L1=ITRI(3,KT)
      JT=J2
      J2=J1
      J1=J3
      J3=JT
  122 CONTINUE
      IF(L1.LT.0) GO TO 123
      KT2=LINE(4,L1)
      GO TO 124
  123 L=-L1
      KT2=LINE(3,L)
  124 IF(KT2.NE.0) GO TO 125
      IER=2
      WRITE(6,1511)
 1511 FORMAT(1X,*IER=2*)
      GO TO 141
  125 CONTINUE
      IF(L1.EQ.-ITRI(1,KT2)) GO TO 126
      IF(L1.EQ.-ITRI(2,KT2)) GO TO 127
      IF(L1.EQ.-ITRI(3,KT2)) GO TO 128
      IER=37
       WRITE(6,1512)
 1512 FORMAT(1X,*IER=37*)
      RETURN
  126 L4=ITRI(2,KT2)
      L5=ITRI(3,KT2)
      GO TO 129
  127 L4=ITRI(3,KT2)
      L5=ITRI(1,KT2)
      GO TO 129
  128 L4=ITRI(1,KT2)
      L5=ITRI(2,KT2)
  129 IF(L4.LT.0) GO TO 130
      J4=LINE(2,L4)
      GO TO 131
  130 L=-L4
      J4=LINE(1,L)
  131 CONTINUE
      IF(L1.LT.0) GO TO 132
      LINE(1,L1)=J
      LINE(5,L1)=FAC*
     1         SQRT((XSCALE*(X(J)-X(J2)))**2+(YSCALE*(Y(J)-Y(J2)))**2)
      GO TO 133
  132 L=-L1
      LINE(2,L)=J
      LINE(5,L)=FAC*
     1       SQRT((XSCALE*(X(J)-X(J2)))**2+(YSCALE*(Y(J)-Y(J2)))**2)
  133 LINE(1,NL+2)=J3
      LINE(2,NL+2)=J
      LINE(3,NL+2)=KT
      LINE(4,NL+2)=NT+1
      LINE(5,NL+2)=FAC*
     1  SQRT((XSCALE*(X(J3)-X(J)))**2+(YSCALE*(Y(J3)-Y(J)))**2)
      LINE(1,NL+1)=J1
      LINE(2,NL+1)=J
      LINE(3,NL+1)=NT+1
      IF(KT2.EQ.0) GO TO 134
      LINE(4,NL+1)=NT+2
      GO TO 135
  134 LINE(4,NL+1)=0
  135 LINE(5,NL+1)=FAC*
     1    SQRT((XSCALE*(X(J1)-X(J)))**2+(YSCALE*(Y(J1)-Y(J)))**2)
      IF(L3.LT.0) GO TO 136
      LINE(3,L3)=NT+1
      GO TO 137
  136 L=-L3
      LINE(4,L)=NT+1
  137 ITRI(1,KT)=L1
      ITRI(2,KT)=L2
      ITRI(3,KT)=NL+2
      ITRI(1,NT+1)=NL+1
      ITRI(2,NT+1)=-(NL+2)
      ITRI(3,NT+1)=L3
      LINE(1,NL+3)=J4
      LINE(2,NL+3)=J
      LINE(3,NL+3)=NT+2
      LINE(4,NL+3)=KT2
      LINE(5,NL+3)=FAC*
     1     SQRT((XSCALE*(X(J)-X(J4)))**2+(YSCALE*(Y(J)-Y(J4)))**2)
      IF(L4.LT. 0) GO TO 138
      LINE(3,L4)=NT+2
      GO TO 139
  138 L=-L4
      LINE(4,L)=NT+2
  139 ITRI(1,NT+2)=-(NL+1)
      ITRI(2,NT+2)=L4
      ITRI(3,NT+2)=NL+3
      ITRI(1,KT2)=-L1
      ITRI(2,KT2)=-(NL+3)
      ITRI(3,KT2)=L5
      CALL STEST(X,Y,LINE,ITRI,L3,FLIP1)
      CALL STEST(X,Y,LINE,ITRI,L2,FLIP2)
      IF(FLIP1.OR.FLIP2) CALL STEST (X,Y,LINE,ITRI,NL+2,FLIP1)
      CALL STEST  (X,Y,LINE,ITRI,L4,FLIP1)
      CALL STEST  (X,Y,LINE,ITRI,L5,FLIP2)
      IF(FLIP1.OR.FLIP2)  CALL  STEST(X,Y,LINE,ITRI,NL+3,FLIP1)
      CALL STEST(X,Y,LINE,ITRI,L1,FLIP1)
      CALL STEST  (X,Y,LINE,ITRI,NL+1,FLIP1)
  140 CONTINUE
      NL=NL+3
      NT=NT+2
  141 CONTINUE
  142 CONTINUE
      RETURN
      END


      SUBROUTINE TMESHI(X,Y,LINE,ITRI,IER)
      COMMON/TRIAN1/NB,NP,XSCALE,YSCALE,XMIN,YMIN,XMAX,YMAX,NL,NT
      COMMON/TRIAN2/ LL(4)
      DIMENSION X(1),Y(1),LINE(5,1),ITRI(3,1)
      LOGICAL FLIP
      LM=NB+1
      KOUNT=3*NL
  101 CONTINUE
      LMIN=LM
      LM=NL
      DO 103 L=LMIN,NL
      IF( LINE(5,L) .LT.0) GO TO 103
      CALL STEST(X,Y,LINE,ITRI,L,FLIP)
      KOUNT=KOUNT-1
      IF(KOUNT.EQ. 0)  GO TO 104
      LINE(5,L)=ISIGN(LINE(5,L),-1)
      IF(.NOT.FLIP) GO TO 103
      DO 102 I=1,4
      LI=IABS(LL(I))
      IF(LINE(4,LI).EQ.0.OR.LINE(3,LI).EQ.0) GO TO 102
      LINE(5,LI)=IABS(LINE(5,LI))
      IF(LI.LT.L) LM=MIN0(LM,LI)
  102 CONTINUE
  103 CONTINUE
      IF(LM.LT.NL) GO TO 101
      GO TO 105
  104 CONTINUE
        IER=3
      WRITE(6,1515)
 1515 FORMAT(1X,*IER=3*)
  105 CONTINUE
      LMIN=NB+1
      DO 106 L=LMIN,NL

      LINE(5,L)=IABS(LINE(5,L))
  106 CONTINUE
      RETURN
      END


      SUBROUTINE TRIANG (X,Y,N,ITRI,ISUP,IUSED,IER)
      DIMENSION  X(N) ,Y(N), ITRI(ISUP)
      COMMON/TRIAN1/NB,NPTS,XSCALE,YSCALE,XMIN,YMIN,XMAX,YMAX,NL,NT
      CALL  CONHUL (X,Y,N,ITRI(2),ITRI(N+3),IER)
      IF (IER .GE. 32) RETURN
      ITRI(1)= NB
      NL = 2*NB+3*(NPTS-NB-2)
      NT =NB+2*(NPTS-NB-2)
      CALL TMESH (X,Y,N,ITRI(2),ITRI(N+3),ITRI(N+3+5*NL),IER)
      IF (IER .GE. 32) RETURN
      CALL TMESHI (X,Y,ITRI(N+3),ITRI(N+3+5*NL),IER)
      IUSED =N+2+5*NL+3*NT
      RETURN
      END


      FUNCTION TRINTR (XX,YY,X,Y,Z,N,ITRI)
      COMMON /TRIAN1/NB,NPTS,XSCALE,YSCALE,XMIN,YMIN,XMAX,YMAX,NL,NT
      DIMENSION X(N),Y(N),Z(N),ITRI(2000)
      IL=N+3
      DMIN=-1.
      ILSAV=0
      DO 102 I=1,NL
      J1=ITRI(IL)
      J2=ITRI(IL+1)
      DX=X(J2)-X(J1)
      DY=Y(J2)-Y(J1)
      DXX=XX-X(J1)
      DYY=YY-Y(J1)
      D=DXX*DX+DYY*DY
      DP=DX*DX+DY*DY
      IF(D.LT.0. .OR. D.GT.DP) GO TO 101
      D=DXX*DXX+DYY*DYY-D*D/DP
      IF(D.LT.0. ) D=0.
      IF(D.GE.DMIN.AND.DMIN.GE.0.) GO TO 101
      DMIN=D
      ILSAV=IL
  101 IL=IL+5
  102 CONTINUE
      K=ITRI(2)
      D=(XX-X(K))**2+(YY-Y(K))**2
      KMIN=K
      DO 105 KK=2,NB
      K=ITRI(KK+1)
      DP=(XX-X(K))**2+(YY-Y(K))**2
      IF(DP.GE.D) GO TO 105
      D=DP
      KMIN=K
  105 CONTINUE
      IF(D.LT.DMIN) GO TO 104
      J1=ITRI(ILSAV)
      J2=ITRI(ILSAV+1)
      DX=X(J2)-X(J1)
      DY=Y(J2)-Y(J1)
      DXX=XX-X(J1)
      DYY=YY-Y(J1)
      K=ITRI(ILSAV+2)
      IF(DX*DYY-DY*DXX.LT.0.) K=ITRI(ILSAV+3)
      IF(K.EQ.0) GO TO 103
      K=N+3+5*NL+3*(K-1)
      L1=IABS(ITRI(K))
      L2=IABS(ITRI(K+1))
      ILSAV=N+3+5*(L1-1)
      J1=ITRI(ILSAV)
      J2=ITRI(ILSAV+1)
      ILSAV=N+3+5*(L2-1)
      J3=ITRI(ILSAV)
      IF(J3.EQ.J2.OR. J3.EQ.J1) J3=ITRI(ILSAV+1)
      F1=1.+((XX-X(J1))*(Y(J2)-Y(J3))+
     1      (YY-Y(J1))*(X(J3)-X(J2)))/
     2          ((X(J2)-X(J1))*(Y(J3) -Y(J2))-
     3            (X(J3)-X(J2))*(Y(J2)-Y(J1)))
      F2=1.+((XX-X(J2))*(Y(J3)-Y(J1))+
     1      (YY-Y(J2))*(X(J1)-X(J3)))/
     2         ((X(J3)-X(J2))*(Y(J1)-Y(J3))-
     3          (X(J1)-X(J3))*   (Y(J3)-Y(J2)))
      F3=1.+((XX-X(J3))*(Y(J1)-Y(J2))+
     1      (YY-Y(J3))*(X(J2)-X(J1)))/
     2      ((X(J1)-X(J3))*(Y(J2)-Y(J1))-
     3      (X(J2)-X(J1))*(Y(J1)-Y(J3)))
      TRINTR=Z(J1)*F1+Z(J2)*F2+Z(J3)*F3
      RETURN
  103 T=(DX*DXX+DY*DYY)/(DX*DX+DY*DY)
      TRINTR=Z(J2)*T+Z(J1)*(1.-T)
      RETURN
  104 CONTINUE
      TRINTR=Z(KMIN)
      RETURN
      END


      PROGRAM DIST(TAPE50,TAPE51=1002B,TAPE52,OUTPUT,TAPE6=OUTPUT)
       DIMENSION XXJ(11,21),SXXJ(11,21),XXJ2(11,21),SXXJ2(11,21)
      DIMENSION DXXJ(11,21),DSXXJ(11,21)
      DIMENSION BLAT(11),BLON(21)
         REAL LHAAT,LMAAT,LTAAT
        DIMENSION PXXJ(11,21),PSXXJ(11,21)
         PI=3.1416
         LHAAT=50.
         LMAAT=250.
         LTAAT=1600.
      JJJ=2
          REWIND 51
      DO 55 II=1,11
       READ(51) BLAT(II)
   55  CONTINUE
       DO 56 JJ=1,21
       READ(51) BLON(JJ)
   56  CONTINUE
          REWIND 50
      DO 200 II=1,11
      READ(50) (XXJ(II,JJ),SXXJ(II,JJ),XXJ2(II,JJ),SXXJ2(II,JJ),
     1 DXXJ(II,JJ),DSXXJ(II,JJ),PXXJ(II,JJ),PSXXJ(II,JJ),JJ=1,21)
  200 CONTINUE
      DO 802 II=1,11
      DO 801 JJ = 1, 21
      XXJ(II,JJ)=XXJ(II,JJ)/FLOAT(JJJ)
      SXXJ(II,JJ)=SXXJ(II,JJ)/FLOAT(JJJ)
      XXJ2(II,JJ)=XXJ2(II,JJ)/FLOAT(JJJ)
      SXXJ2(II,JJ)=SXXJ2(II,JJ)/FLOAT(JJJ)
  801 CONTINUE
  802 CONTINUE
          ASULFUR=0.0
           DSULFUR=0.0
          PSULFUR=0.0
           DO 111 II=1,11
           DO 112 JJ=1,21
           AAA=(BLAT(II)-0.5)*PI/180.0
           BBB=COS(AAA)
           C1=(XXJ(II,JJ)/2.0+SXXJ(II,JJ)/3.0)
           D1=1.20165*10.0*BBB*(LMAAT-LBAAT)
           C2=XXJ2(II,JJ)/2.0+SXXJ2(II,JJ)/3.0
           D2=1.20165*10.0*BBB*(LTAAT-LMAAT)
          C3=DXXJ(II,JJ)/2.0+DSXXJ(II,JJ)/3.0
           D3=1.2065*10000.0*BBB
           TSUL =C1*D1+C2*D2
           DSUL =C3*D3
           ASULFUR=ASULFUR+TSUL
          C4=PXXJ(II,JJ)/2.0+PSXXJ(II,JJ)/3.0
          PSUL=C4*D3
          PSULFUR=PSULFUR+PSUL
           DSULFUR=DSULFUR+DSUL
  112      CONTINUE
  111      CONTINUE
C*********ASULFUR IS THE AMOUNT OF SULFUR(KG) IN THE AIR AND
C          DSULFUR IS THE DEPOSITED AMOUNT OF SULFUR ON THE SURFACE(KG)**
      WRITE(6,914)
  914 FORMAT(1H1,8X,* CONCENTRATION OF SO2 AT SURFACE LEVEL(MIGRAM/M3)*
     Z////)
      WRITE(6,915) (BLON(JJ),JJ=1,16)
  915 FORMAT(8X,16F8.1/////)
      DO 903 II=1,11
      WRITE(6,904) BLAT(II),(XXJ(II,JJ),JJ=1,16)
  904 FORMAT(F8.1,16E8.2////)
  903 CONTINUE
      WRITE(6,925) (BLON(JJ),JJ=17,21)
  925 FORMAT(1H1,8X,5F8.1/////)
      DO 913 II=1,11
      WRITE(6,941) BLAT(II),(XXJ(II,JJ),JJ=17,21)
  941 FORMAT(F8.1,5E8.2////)
  913 CONTINUE
      WRITE(6,950)
  950 FORMAT(1H1,8X,* CONCENTRATION OF SO4 AT SURFACE LEVEL(MIGRAM/M3)*
     Z////)
      WRITE(6,915) (BLON(JJ),JJ=1,16)
      DO 951 II=1,11
      WRITE(6,904) BLAT(II),(SXXJ(II,JJ),JJ=1,16)
  951 CONTINUE
      WRITE(6,925) (BLON(JJ),JJ=17,21)
      DO 952 II=1,11
      WRITE(6,941) BLAT(II),(SXXJ(II,JJ),JJ=17,21)
  952 CONTINUE
      WRITE(6,953)
  953 FORMAT(1H1,8X,*DEPOSITION OF SO2(KG/KM2)*////)
      WRITE(6,915) (BLON(JJ),JJ=1,16)
      DO 954 II=1,11
      WRITE(6,904) BLAT(II),(DXXJ(II,JJ),JJ=1,16)
  954 CONTINUE
      WRITE(6,925) (BLON(JJ),JJ=17,21)
      DO 955 II=1,11
      WRITE(6,941) BLAT(II),(DXXJ(II,JJ),JJ=17,21)
  955 CONTINUE
      WRITE(6,956)
  956 FORMAT(1H1,8X,*DEPOSITION OF SO4(KG/KM2)*////)
      WRITE(6,915) (BLON(JJ),JJ=1,16)
      DO 957 II=1,11
      WRITE(6,904) BLAT(II),(DSXXJ(II,JJ),JJ=1,16)
  957 CONTINUE
      WRITE(6,925) ( BLON(JJ),JJ=17,21)
      DO 958 II=1,11
      WRITE(6,941) BLAT(II),(DSXXJ(II,JJ),JJ=17,21)
  958 CONTINUE
      WRITE(6,970)
  970 FORMAT(1H1,8X,*CONCENTRATION OFSO2 ABOVE B. LAYER(MIGRAM/M3)*
     Z////)
      WRITE(6,915) (BLON(JJ),JJ=1,16)
      DO 971 II=1,11
      WRITE(6,904) BLAT(II),(XXJ2(II,JJ),JJ=1,16)

  971 CONTINUE
      WRITE(6,925) (BLON(JJ),JJ=17,21)
      DO 972 II=1,11
      WRITE(6,941) BLAT(II),(XXJ2(II,JJ),JJ=17,21)
  972 CONTINUE
```

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      WRITE(6,980)
 980  FORMAT(1H1,8X,*CONCENTRATION OF SULFATE ABOVE B.LAYER(MIGRAM/M3)*
     Z/////)
      WRITE(6,915) (BLON(JJ),JJ=1,16)
      DO 981 II=1,11
      WRITE(6,904) BLAT(II),(SXXJ2(II,JJ),JJ=1,16)
 981  CONTINUE
      WRITE(6,925) (BLON(JJ),JJ=17,21)
      DO 982 II=1,11
      WRITE(6,941) BLAT(II),(SXXJ2(II,JJ),JJ=17,21)
 982  CONTINUE
        WRITE(6,700)
 700    FORMAT(1H1,8X,*DEPOSISION OF SO2 DUE TO RAIN(KG/KM2)*////)
        WRITE(6,915) (BLON(JJ),JJ=1,16)
        DO 710 II=1,11
        WRITE(6,904) BLAT(II),(PXXJ(II,JJ),JJ=1,16)
710     CONTINUE
        WRITE(6,925) (BLON(JJ),JJ=17,21)
        DO 720 II=1,11
        WRITE(6,941) BLAT(II),(PXXJ(II,JJ),JJ=17,21)
 720    CONTINUE
        WRITE(6,730)
 730    FORMAT(1H1,8X,*DEPOSISION OF SULFATE DUE TO RAIN(KG/KM2)*////)
        WRITE(6,915) (BLON(JJ),JJ=1,16)
        DO 740 II=1,11
        WRITE(6,904) BLAT(II),(PSXXJ(II,JJ),JJ=1,16)
 740    CONTINUE
        WRITE(6,925) (BLON(JJ),JJ=17,21)
        DO 750 II=1,11
        WRITE(6,941) BLAT(II),(PSXXJ(II,JJ),JJ=17,21)
 750    CONTINUE
        WRITE(6,850) ASULFUR
 850     FORMAT(1H1,10X,*AMOUNT OF SULFUR(KG) IN THE AIR=*,F15.1)
         WRITE(6,851) DSULFUR
 851     FORMAT(10X,*DEPOSITED AMOUNT OF SULFUR(KG) =*,F15.1)
        WRITE(6,852) PSULFUR
 852    FORMAT(10X,*RAIN DEPOSISION OF SULFUR(KG)=*,F15.1)
        REWIND 52
        READ(52) ADSO2,ADSULF,APSO2,APSULF,ATSUL
        WRITE(6,1111) ADSO2
        WRITE(6,1112) ADSULF
        WRITE(6,1113) APSO2
        WRITE(6,1114) APSULF
        WRITE(6,1115) ATSUL
1111     FORMAT(1H1,10X,*DRY DEPOSITION OF SO2(KG)=*,E15.5)
1112    FORMAT(10X,*DRY DEPOSITION OF SO4(KG)=*,E15.5)
1113    FORMAT(10X,*WET DEPOSITION OF SO2(KG)=*,E15.5)
1114    FORMAT(10X,*WET DEPOSITION OF SO4(KG)=*,E15.5)
1115    FORMAT(10X,*TOTAL DEPOSITION OF SULFUR=*,E15.5)
      STOP
      END


      PROGRAM INIT(TAPE50,TAPE51=1002B,TAPE52)
       DIMENSION BLAT(11),BLON(21)
      DIMENSION XXJ(11,21),SXXJ(11,21),XXJ2(11,21),SXXJ2(11,21)
      DIMENSION DXXJ(11,21),DSXXJ(11,21)
       DIMENSION PXXJ(11,21),PSXXJ(11,21)
      DO 500 II=1,11
       BLAT(II)=0.0
 500   CONTINUE
       DO 501 JJ=1,21
       BLON(JJ)=0.0
 501   CONTINUE
      DO 20 II=1,11
      DO 10 JJ=1,21
      XXJ(II,JJ)=0.0
      SXXJ(II,JJ)=0.0
      XXJ2(II,JJ)=0.0
      SXXJ2(II,JJ)=0.0
      DXXJ(II,JJ)=0.0
      DSXXJ(II,JJ)=0.0
        PXXJ(II,JJ)=0.0
          PSXXJ(II,JJ)=0.0
  10  CONTINUE
  20  CONTINUE
      DO 505 II=1,11
      WRITE(51) BLAT(II)
 505  CONTINUE
      DO 506 JJ=1,21
      WRITE(51) BLON(JJ)
 506  CONTINUE
      DO 40 II=1,11
      WRITE(50) (XXJ(II,JJ),SXXJ(II,JJ),XXJ2(II,JJ),SXXJ2(II,JJ),
     1 DXXJ(II,JJ),DSXXJ(II,JJ),PXXJ(II,JJ),PSXXJ(II,JJ),JJ=1,21)
  40  CONTINUE
       ADSO2=0.0
       ADSULF=0.0
 APSO2=0.0
 APSULF=0.0
 ATSUL=0.0
 REWIND 52
 WRITE(52) ADSO2,ADSULF,APSO2,APSULF,ATSUL
STOP
END
```